AN INVESTIGATION INTO THE EFFECT OF AN INDUSTRIAL HEAT AND MOISTURE SOURCE ON LOCAL ATMOSPHERIC CONDITIONS

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THESIS

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by

James Clinton Kraft

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An Investigation into the Effect of an
Industrial Heat and Moisture Source on
Local Atmospheric Conditions

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Lieutenant, United States Navy
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ABSTRACT

Using a steam electric generating plant as the source, an investigation was made into the local atmospheric effect of a large industrial heat and moisture source. Data collection was attempted with ground- and helicopter-borne equipment with a final resort to the helicopter when the ground equipment collection techniques proved unsatisfactory. Cross sections of temperature and moisture were drawn from this data and yielded some very interesting profiles.

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TABLE OF SYMBOLS AND ABBREVIATIONS

Abbreviation	Definition
MW	megawatt
g	gram
fpm	feet per minute
RH	relative humidity
mb	millibar
m_s	saturated mixing ratio
m	mixing ratio
e_s	saturated vapor pressure
e	vapor pressure
BTU	BRITISH Thermal Unit
R_v	gas constant for water vapor
L_{lv}	latent heat of vaporization
C	degrees Celsius

ACKNOWLEDGMENTS

I wish to thank Lieutenant Commander R. N. Whalen, USN, for his work, assistance, and flight time with the helicopter wiresonde. Also, thanks to Mr. Russel D. Schwanz and Mr. Stephen K. Renard for their assistance in the many operational facets of the helo wiresonde, especially the rigging, unrigging, and transportation to and from the airport. My thanks also go to PO1 James Garrett, USN, and Mr. P. R. Adler for their uncomplaining assistance in the field while attempting to use the balloon-supported wiresonde; to Mr. Michael B. McDermet for his drafting assistance and for providing the on-the-job training I needed to complete the many graphs required; to my advisor, Associate Professor C. L. Taylor for presenting me with the idea for this study and then providing just the right amount of guidance so that I did not feel unduly burdened by the many outside interests which touched this study. My thanks go to the Pacific Gas and Electric Company and their personnel at the Moss Landing Power Plant for their assistance during this project. Finally, thanks to my wife who overcame my poor penmanship and typed through this paper twice in order to make it reasonably presentable. She also gallantly and quietly suffered through the many early morning risings required to get me to the flight line early enough to check out and mount the equipment.

I. INTRODUCTION

The west coast of the United States presents a unique meteorological laboratory, having a reasonably uniform, but very temperamental climate. The prevailing westerly winds, coastal upwelling of cold waters, coastal mountain ranges, and the predominating Eastern Pacific Subtropical Anticyclone all interact along the coast to form this environ.

It is unique in that the cold upwelling waters interact with the relatively moist air flowing off the ocean and over the coast to form the common and persistent "west coast inversion". Subsiding warm, dry air from the Eastern Pacific Subtropical Anticyclone further intensifies this inversion and traps the moisture in the first few hundred meters. It also traps anything else that might be injected into the atmosphere at low levels and severely hinders pollutant dispersal.

The inversion is generally much more common and intense in summer, although it is present in other months. Both Neiburger, et al. (1961) (1) and Haraguchi (1968) (2) found the inversion present to a greater or lesser extent during extended cruises in the mid-Pacific. Neiburger traced it all the way to Tahiti. Both, however, found the inversion much more intense and much lower along the west coast.

With continued growth of population along the California coast, additional coastal industry is a normal consequence. What effects of a large industrial heat and moisture source would be on the inversion-dominated weather is an intriguing question indeed. Aside from the question of pollutants, what would be the effects of a known amount of heat and moisture released into the atmosphere at low levels, generally at or below the base of the inversion? Would the inversion be intensified, reduced, raised, lowered, or dispersed? This project addressed itself to these questions.

II. NATURE OF THE RESEARCH

A. DESCRIPTION OF THE INDUSTRIAL SITE

A large industrial heat source is located on the California coast at Moss Landing, approximately 16 miles north of Monterey on Monterey Bay. The source is a Pacific Gas and Electric Company steam generating plant (Fig. 1). It is one of the largest such plants in the world and at full load generates 2.1 MW of electric power while consuming 19 million ft^3 of natural gas per hour.

Boiler efficiency runs from about 80% on the eight smaller and older units (total gas capacity seven million ft^3 per hour) to 87-90% on the newer super-critical units (gas capacity six million ft^3 per hour on each of the two units).

Stack height from these two units is 500 ft. At full capacity they account for about 60% of all waste products. Since they are the most efficient of the installed units, they are in service continuously with the smaller units brought on as the load requires. Thus the large stacks generally account for most, if not all, of the waste emissions.

Simple arithmetic tells us that, at an average heat capacity of 1075 BTU's per cubic foot of gas, the plant at full power releases about 3.06×10^8 (306 million) BTU's per hour to the atmosphere. This is 78×10^{10} (780 billion) calories, quite a sizeable and concentrated heat source.

Additionally, a by-product of the combustion of a hydrocarbon and oxygen is water vapor. In this case roughly one million gallons of water per hour are formed in the boiler fire boxes and released up the stacks. If this water were all precipitated out, it would be equivalent to about three acre-feet of water.

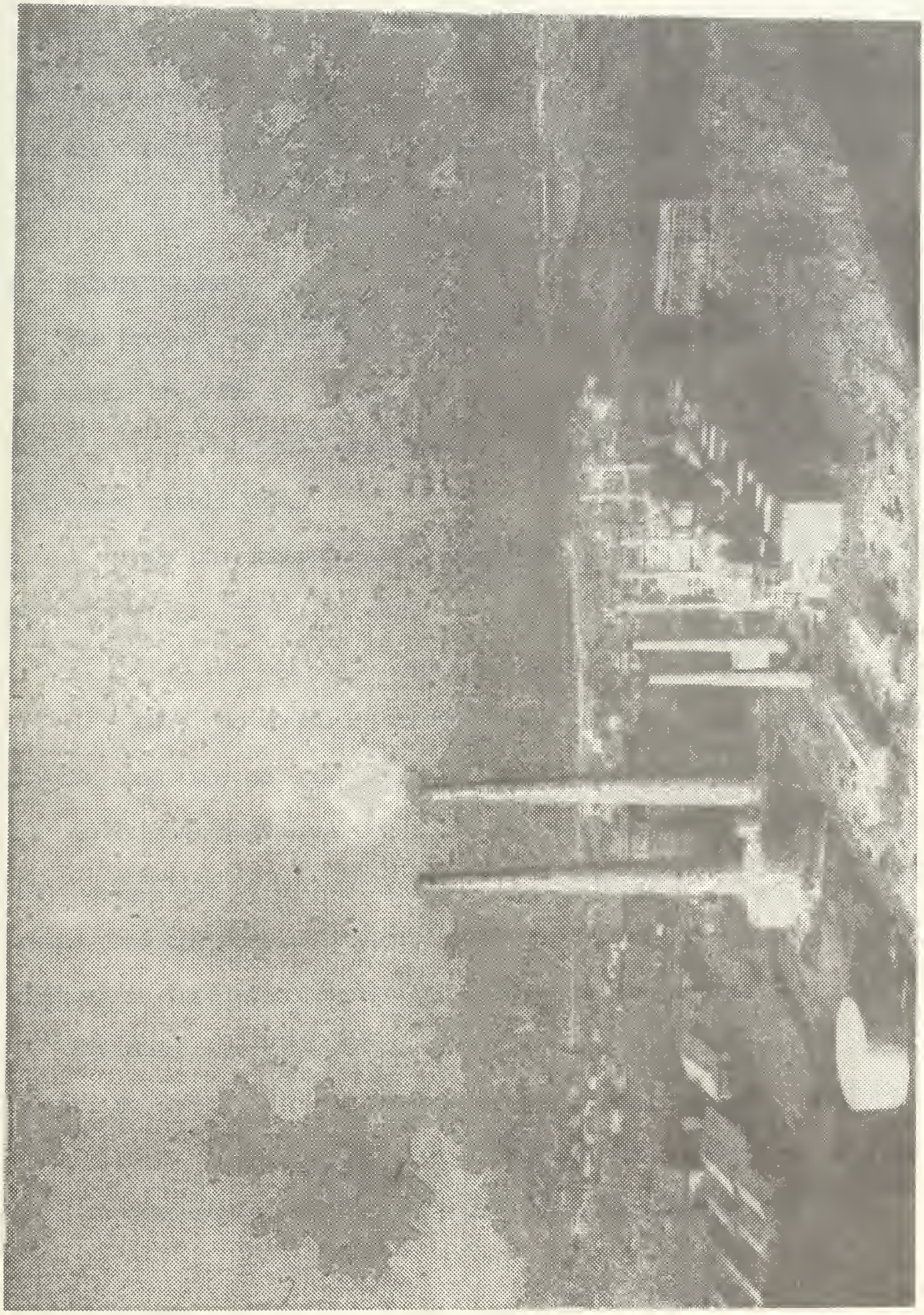

FIGURE 1

A large portion of the plant's generating capacity feeds California's central valley. A rich farming area, the valley's demand for electricity reaches a peak during the summer months in the form of irrigation pumps and air conditioning. This is precisely when the coastal regions are most affected by the inversion regime.

B. PROJECT AIMS

The project, as initially conceived and subsequently carried out, was to deduce the effect, if any, of the plant's waste heat and exhausted moisture upon the local atmosphere. The questions to which the project addressed itself were:

1. Does the exhaust heat significantly raise or disperse the inversion, when the inversion is present?

2. Could the moisture have any effect on the inversion?

3. Could the combination of the two effects (heat and moisture) have, in the long run, no appreciable effect on the inversion?

Additional questions considered, but not directly addressed, included the possibility of narrow layers of high instability, super-adiabatic lapse rates, and the possibility of increased rainfall due to moisture input or changes in insolation due to the effects on the inversion.

Equipment was required to obtain a dense array of data at selected points in the power plant area, with additional reference and control points at similarly situated geographic locations for comparison. The equipment used and procedures selected are described in Section III.

III. EXPERIMENTAL PROCEDURES

A. DESCRIPTION OF EQUIPMENT

1. The Wiresonde Set

The Wiresonde Set (Navy Designation AN/UMQ-3) was initially considered the prime instrument for data collection. Manufactured by the Friez Instrument Division of Bendix Aviation Corporation, the set consists of three basic units.

The Wiresonde (Airborne Unit, ML-369/UMQ-3) is the sensing unit (Fig. 2). The aluminum housing contains a rod thermistor as a temperature sensor and a standard radiosonde humidity element. Also contained is a ventilation motor designed to be driven by two PIBAL batteries. Due to the relative obsolescence of the equipment, the required batteries were no longer available. A battery clip with four penlight dry cells was taped to the exterior of the housing and served adequately as a blower motor power source (Fig. 3).

The Cable Reel (RL-116/UMQ-3) is a hand-cranked reel containing 3000 feet of three-conductor fiber glass reinforced cable (kite cord) (Fig. 2). A drum-mounted counter calibrated in "feet of cable" indicated the amount of cable deployed. The reel swivels through 360° and is controlled by a hand-operated expanding friction brake.

The Temperature-Humidity Bridge (ML-370/UMQ-3) is a manually adjusted instrument which measures the resistance in the temperature and humidity elements (the sensing elements in the wiresonde) in terms of arbitrary dial indications. The dial readings are then converted to temperature and relative humidity data from accompanying charts.

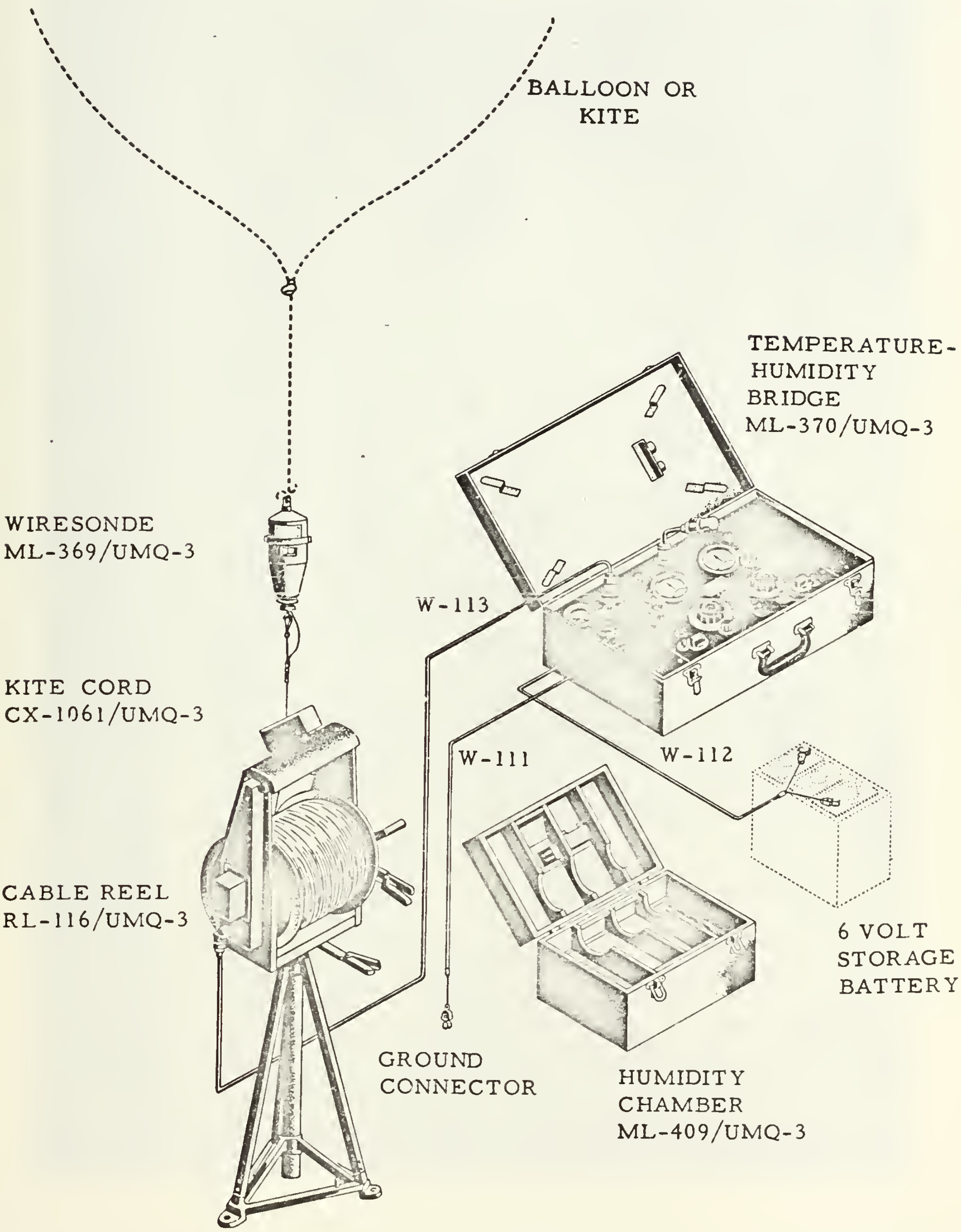
BALLOON OR KITE
TEMPERATURE-HUMIDITY BRIDGE ML-370/UMQ-3
WIRESONDE ML-369/UMQ-3
W-113
KITE CORD CX-1061/UMQ-3
W-111
W-112
CABLE REEL RL-116/UMQ-3
6 VOLT STORAGE BATTERY
GROUND CONNECTOR
HUMIDITY CHAMBER ML-409/UMQ-3

FIGURE 2

FIGURE 3

The wiresonde is raised by a balloon or kite. In this instance two 300g balloons were filled with 100 ft^3 of helium each, tethered to together, and attached to the wiresonde (Fig. 4). Heights above ground were determined by measuring elevation angle with a clinometer and, assuming negligible catenary, trigonometrically reduced to height data.

Additional information concerning the equipment is contained in Ref. 3.

2. The Helicopter Aerograph Set

The Helicopter Aerograph Set (Navy Designation AN/AMQ-18) became available early in the project and proved to be a most worthwhile piece of equipment. Manufactured by the U. S. Naval Avionics Facility, Indianapolis, Indiana, the set contains two basic elements.

The Wiresonde Unit (ML-578/AMQ-18) (Fig. 5) is a streamlined package containing 50 feet of cable, cable winch, pressure sensing bellows, and a temperature/humidity vortex tube sensor. A fan forces air through the vortex tube at high velocities. Condensed water, if present, is forced to the outside walls of the tube away from the temperature sensor eliminating the "wet bulb effect". This additionally prevents the washing of the electrolyte from the humidity sensor.

The tolerance limits specified by the manufacturer are:

Temperature: ±0.5C

Relative Humidity: ±6%.

Pressure: ±10mb.

The wiresonde unit transmits data to an Indicator Recorder (I-A) (AN/AMA-2) (Fig. 6) within the aircraft cabin by an electro-mechanical servo system. The I-A unit gives a continuous display of measured parameters and additionally prints the reading every eight seconds.

FIGURE 4

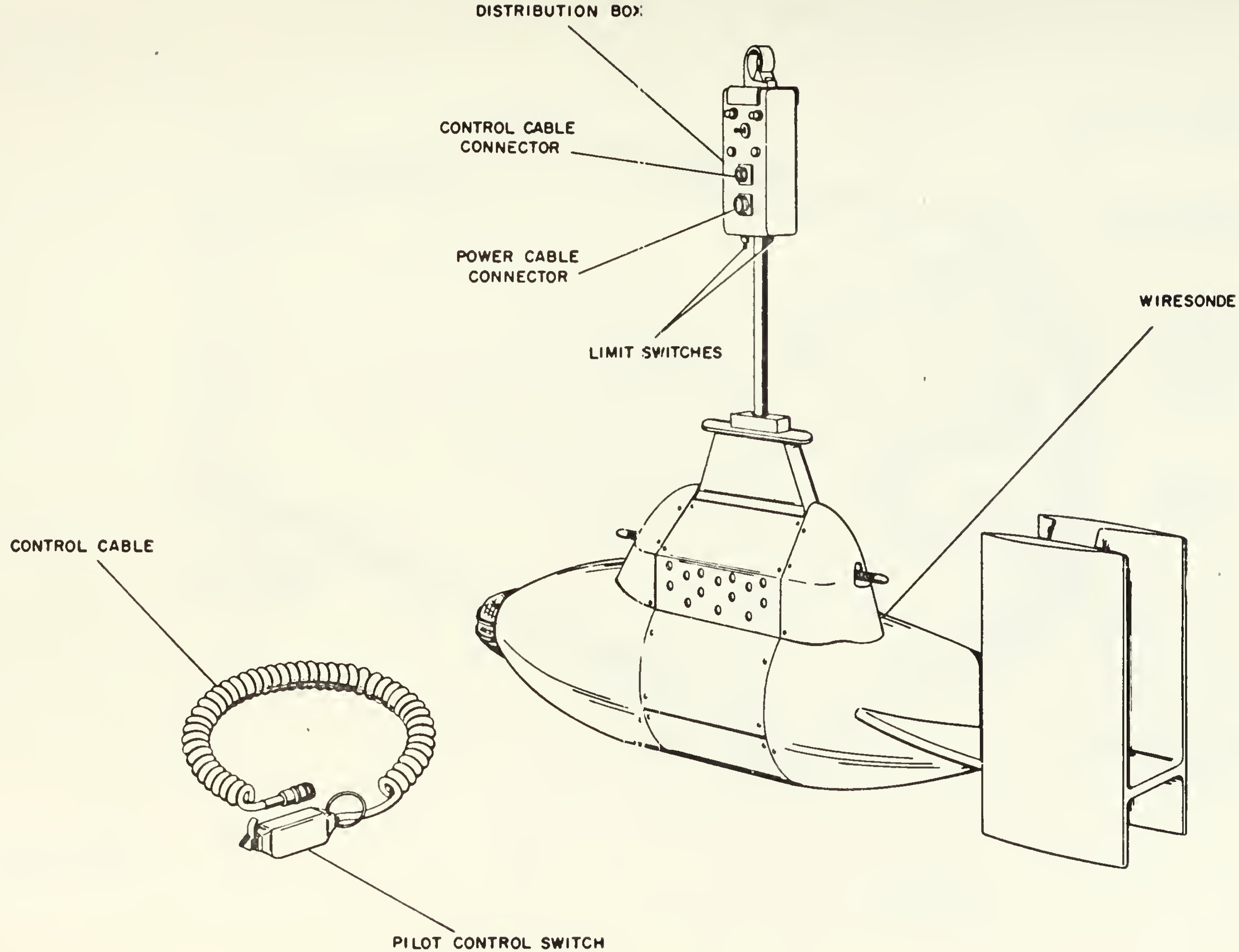
DISTRIBUTION BOX
CONTROL CABLE CONNECTOR
POWER CABLE CONNECTOR
LIMIT SWITCHES
WIRESONDE
CONTROL CABLE
PILOT CONTROL SWITCH

FIGURE 5

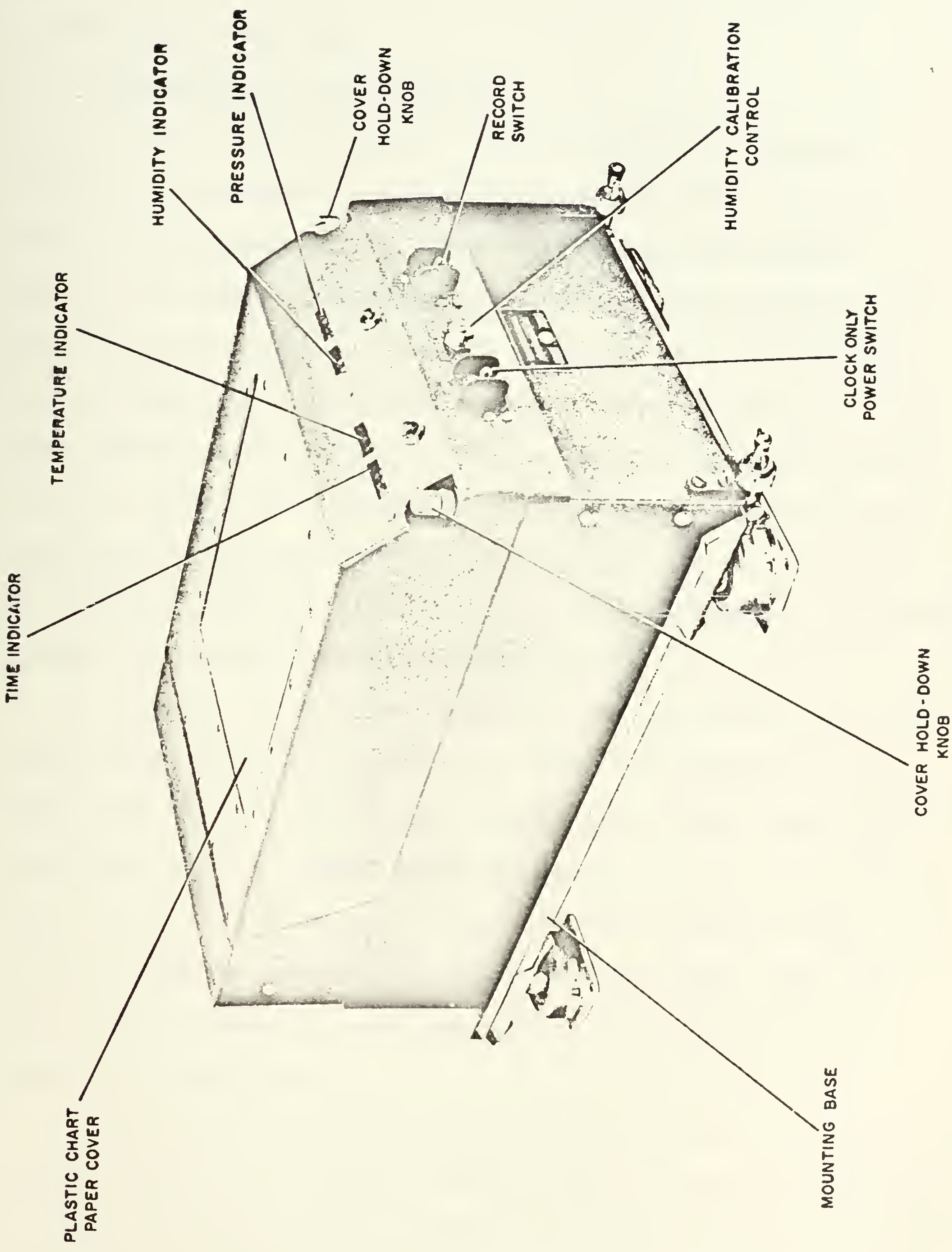
HUMIDITY INDICATOR
PRESSURE INDICATOR
COVER HOLD-DOWN KNOB
RECORD SWITCH
HUMIDITY CALIBRATION CONTROL
TEMPERATURE INDICATOR
CLOCK ONLY POWER SWITCH
TIME INDICATOR
COVER HOLD-DOWN KNOB
PLASTIC CHART PAPER COVER
MOUNTING BASE

FIGURE 6

Additional information concerning the equipment is contained in Ref. 4.

B. EMPLOYMENT OF EQUIPMENT

1. Employment of the Wiresonde Set

It was initially decided to use the ground-based wiresonde (AN/UMQ-3) as the primary instrument for data collection. Procedures called for establishing a grid over which soundings would be made up to 3000 ft, if possible. The grid array was to be selected to take the best advantage of the local topographic and geographic features of the Moss Landing region. Lacking any experience with the equipment, it was hoped that a fairly dense network of eight to ten data points could be sampled in a day. Pacific Gas and Electric officials were also contacted about the possibility of establishing a sounding location on the roof of one of their plant buildings. Several sights were inspected, but no location favorable to all parties could be agreed upon.

A dry run to 100 ft was conducted at the Naval Postgraduate School using one balloon and about 100 ft^3 of helium. No difficulties were experienced. Since the school is in the Monterey Airport flight path, the sounding was limited to 100 ft, thus the maximum altitude in this configuration could not be determined. The balloon was inflated for about 2000g of lift. Since the instrument package weighs about 425g and the cable weighs 1.3kg per 1000 ft, it was assumed that this configuration was adequate for about 1000 ft.

The first field trial of the equipment on 5 March 1971 proved to be less than successful. A pickup truck was used to transport the equipment to a site on the Moss Landing beachfront. The dry run configuration proved to be good for only about 400 ft. The balloon was winched back down and

filled to almost double its capacity (approximately 150 ft^3 of helium) and sent back aloft. This increased maximum altitude to about 1000 ft. Readings were taken at 100 foot increments.

At this point wind began to present a problem. An over-inflated meteorological balloon provides a large sail area and it is severely buffeted by even the slightest breeze.

An attempt to move to a second location with the balloon still inflated was a ticklish maneuver, but was completed, a distance of about two miles, in 20 minutes with the balloon intact. However, the balloon burst while being rigged and the station was abandoned. A third attempt for the day ended abruptly when the cable parted at the instrument package and the balloon, package, battery pack, etc., were lost.

The first trial ended with one sounding to 1000 ft.

Three additional attempts ended in failure as follows:

a. One sounding to 2000 ft, second sounding aborted due to personnel injury.

b. One sounding to 1900 ft, no second sounding attempted due to high winds.

c. The day's attempts aborted due to inoperative equipment.

It was also found that balloon handling in winds over about five knots, as measured by a hand-held anemometer on the sight, became extremely tricky. Soundings in these winds proved to be more horizontal than vertical, endangering operating personnel due to the proliferation of power lines in the area.

Soundings also took an excessive amount of time, especially the winching-in process. An average time from beginning of bench check to having the equipment loaded and ready to move to a new sight was two and one-half to three hours. Thus the desire for a fairly dense network of soundings quickly became a pipedream and a good day would yield from two to four soundings.

This method of data gathering was subsequently abandoned in favor of the helicopter aerograph set.

2. Employment of the Helicopter Aerograph Set

Whalen (1971) (6) conducted extensive testing of the Helicopter Aerograph Set (AN/AMQ-18) from mid-July 1970 to January 1971 with actual flight tests occurring from 11 September 1970 to 22 January 1971. The equipment was successfully flight tested in its final configuration on 22 January 1971, though several post-test flights were made into the spring.

Though designed to be flown while freely suspended from its cable, the wiresonde unit was discovered by Whalen to be quite unstable in a crosswind. A frame was designed and the instrument rigidly mounted to the exterior step at the aircraft's cabin door (Fig. 7). Subsequent testing found this to be a most satisfactory rig and in this position the wiresonde unit was neither affected by rotor wash nor shielded by external aircraft structures.

Due to continuing problems with the recording feature of the indicator-recorder unit, the recording portion was not used. In its stead a data sheet was used (Appendix 1). An operator in the cabin, hooked into the aircraft's Internal Communications System (ICS), can converse with the pilot in flight, thus getting accurate position and altitude data.

Soundings were taken by flying in a tight climbing turn with an indicated airspeed of 70 knots and at an ascent rate of about 300fpm over a pre-selected geographic position. These positions were selected primarily to be free of housing, power transmission lines, domestic farm animals, etc., and also to be fairly prominent geographically (river mouth, road intersection, etc.) so that re-visits on subsequent flights could easily be made. Figure 8 shows the geographic location of the power plant.

Soundings were made beginning, if possible, at 100 feet above sea level. All altitudes were based on the barometric altimeter. Data were recorded in 100 foot increments based on altitude signals from the pilot of the aircraft over the ICS. Due to aircraft operating safety precautions, all soundings were terminated at 3000 ft or at the base of the clouds, whichever was lower.

Numerous different patterns of soundings were flown, including flights as far as 60 miles from the Moss Landing area in the vicinity of King City. A final sounding pattern was established on 11 June 1971, consisting of one over-bay sounding, three coastal soundings, and three soundings several miles inland from the coastal soundings and roughly normal to the coast. Figure 8 also shows a schematic of this final pattern.

C. DATA REDUCTION

Given temperature (T) in degrees Kelvin, pressure (P) in millibars, and relative humidity (RH) in percent, mixing ration (m) can be found as follows[1]:

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[1]Haltiner, G. J. and Martin, F. L., Dynamical and Physical Meteorology, p. 24-25, McGraw-Hill, 1957.

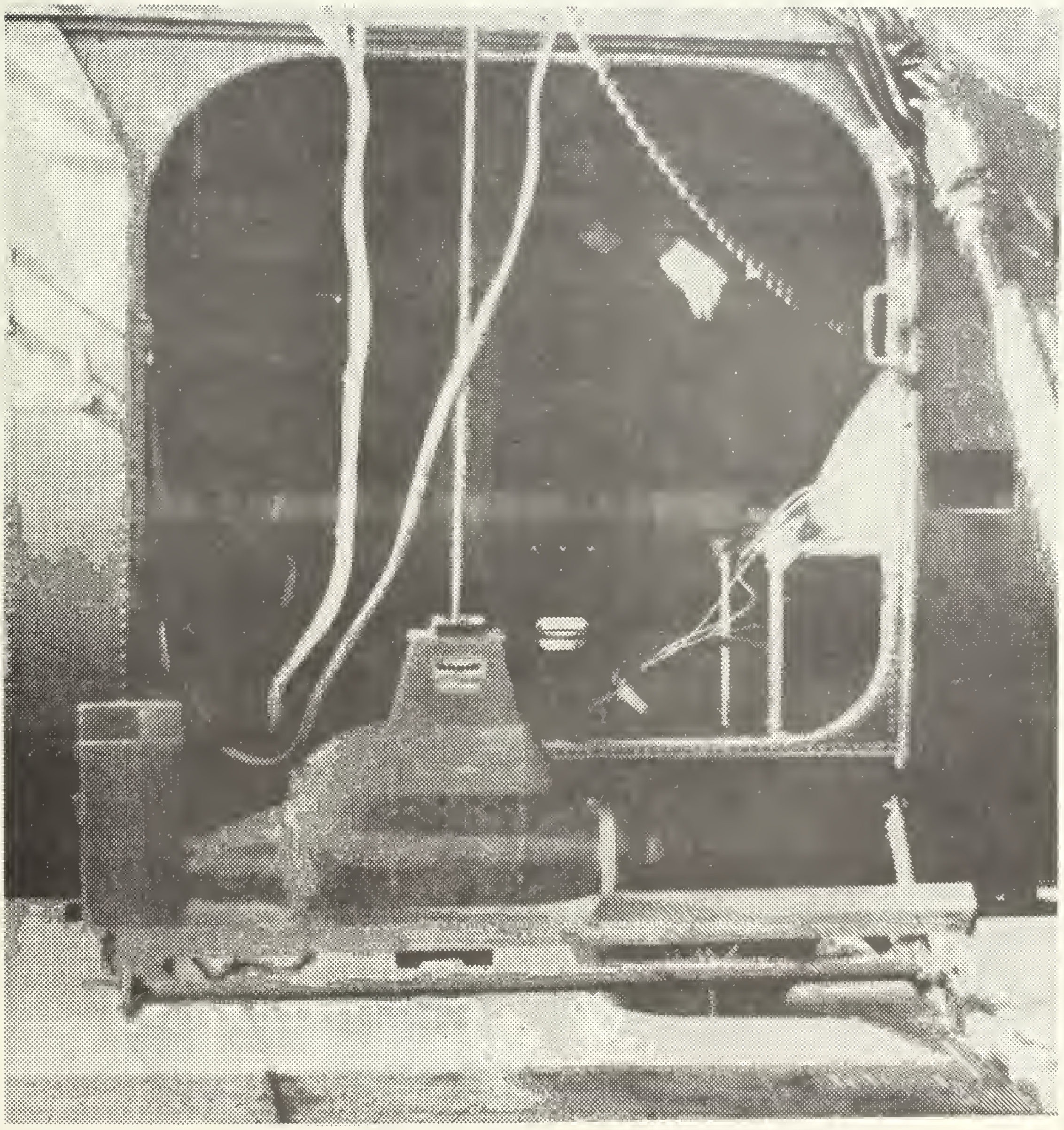


FIGURE 7

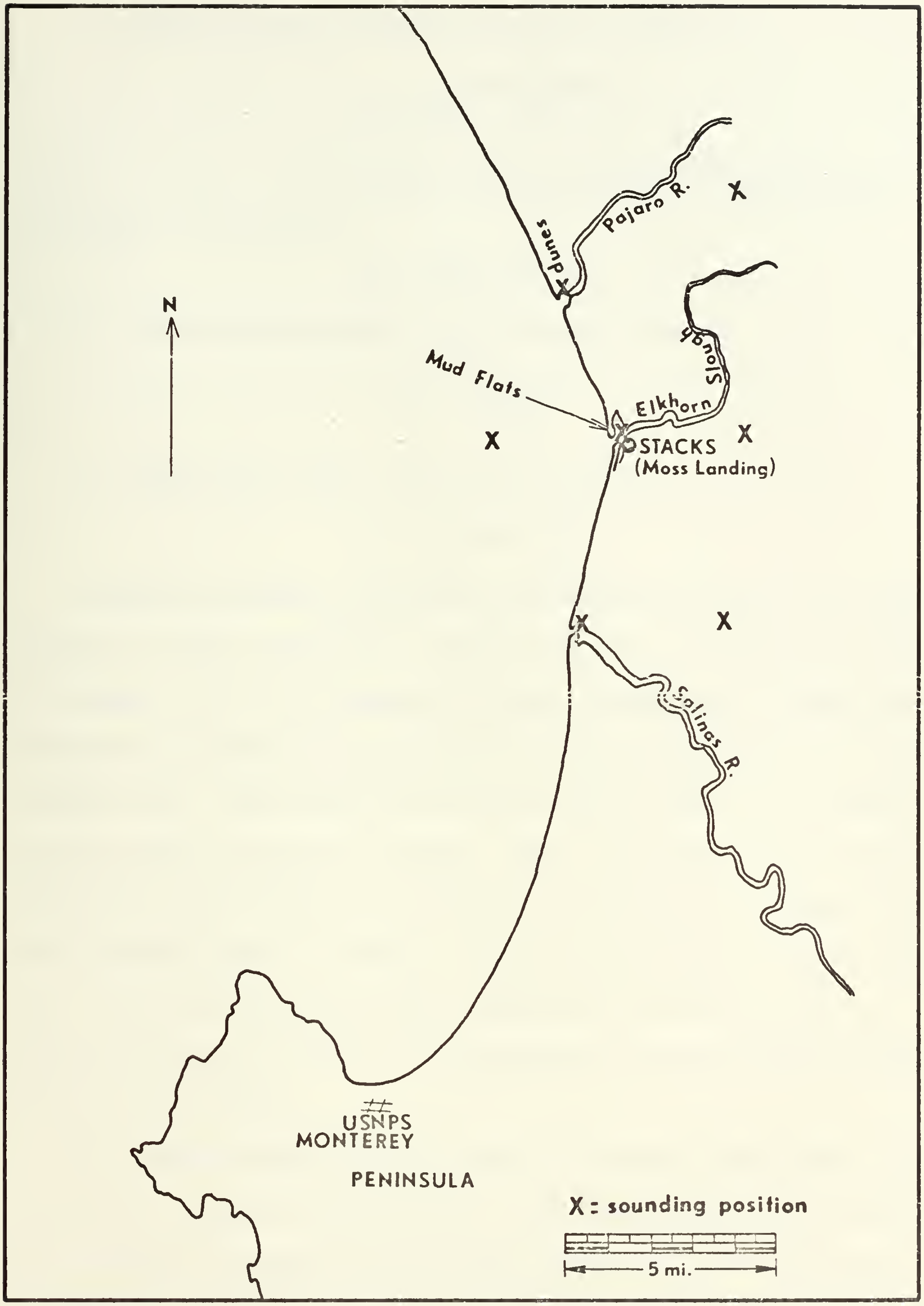

N
Pajaro R.
dunes
Slough
Mud Flats
Elkhorn
STACKS
(Moss Landing)
Salinas R.
USNPS
MONTEREY
PENINSULA
X : sounding position
5 mi.

FIGURE 8

1. Saturated vapor pressure (e_s) in mb is given by

$$e_s = 6.11e^{A(1/T_0-1/T)}$$

where $A = L_{lv}/R_v$, the latent heat of vaporization divided by the gas constant for water vapor.

$$T_0 = 273.1° \text{ Kelvin}$$

2. Saturated mixing ratio (m_s) in g/kg is given by

$$m_s = \frac{.622(e_s)}{P - e_s}$$

3. Mixing ratio (m) in g/kg is then found by

$$m = (m_s)(RH)(100).$$

Since the helicopter aerograph set generates as direct data outputs pressure in mb, temperature in degrees Celsius, and relative humidity in percent, it is only necessary to convert temperature to degrees Kelvin, substitute all generated quantities into the above equations, and obtain mixing ratio. Mixing ratio was chosen because it would give a quantitative value of moisture in the air. Thus, if in the vicinity of the generating plant there was an increase in moisture and temperature, relative humidity might not indicate a change in water vapor content. It was felt that mixing ratio would more realistically reflect the actual moisture contained in the air and, therefore, be more suitable for the aims of this project.

The IBM-360 computer system located at the Naval Postgraduate School was used to execute this conversion. Use of the computer was desirable not only from the aspect of elimination of drudgery, but also from the standpoint that the data could be key punched, cataloged, and arranged in a convenient manner for future users.

A program in the simple modified WATFOR version of FORTRAN was developed, designated WATFIV by the Postgraduate School Computer Center. Formatted input and output were used to ease conversion to normal FORTRAN language if desired. Normal run-times never exceeded one second and core usage never exceeded 5K bytes. Thus the program easily handled the designed task, digesting the 600-700 data points per day's observations in a minimum of machine time and core usage.

An example of the final program is contained in Appendix B.

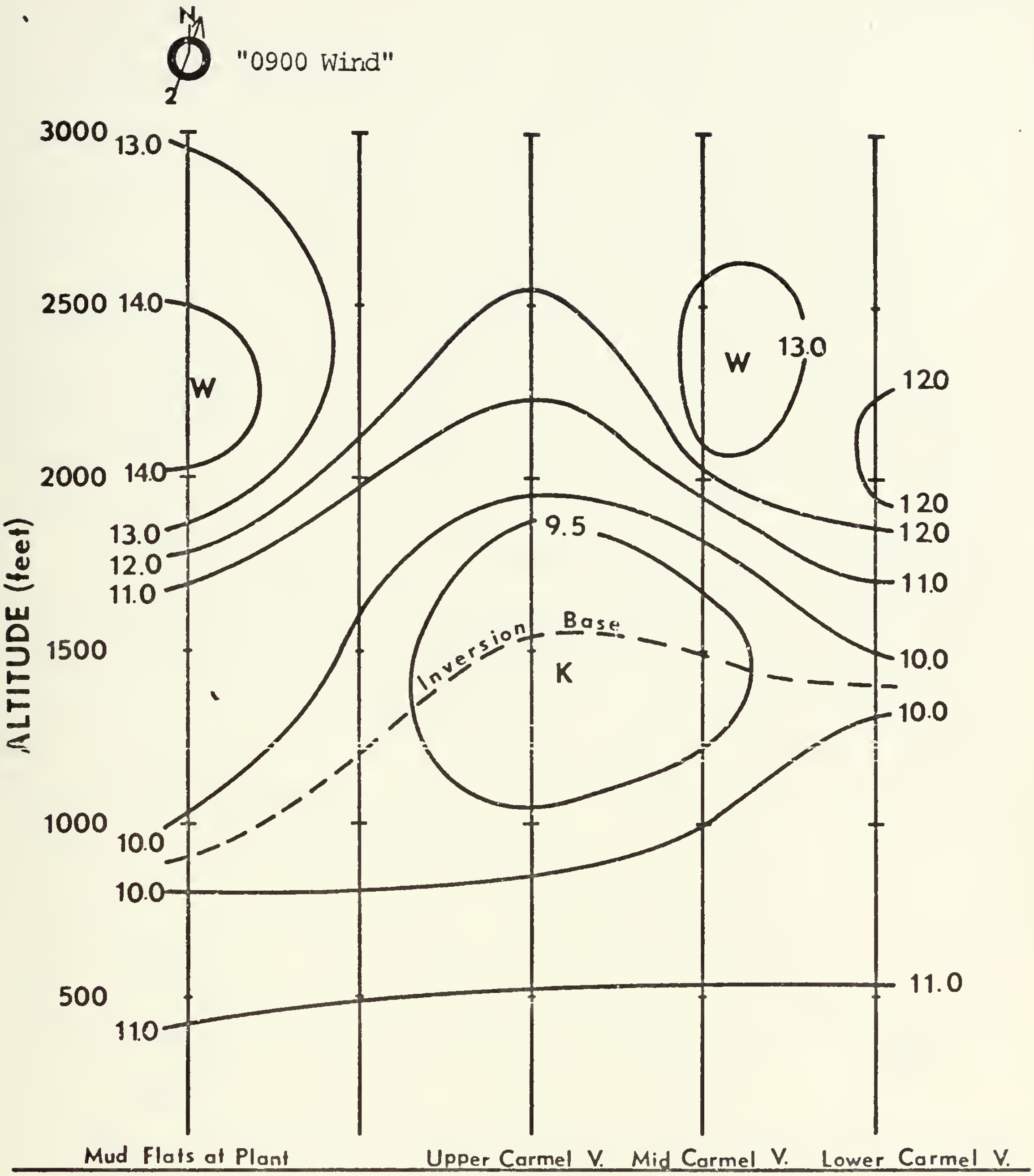
IV. PRESENTATION OF DATA

Having generated mixing ratios for all data points, a useable form for displaying the data was required. Vertical cross sections of temperature and mixing ratio were used. A wind rose is shown on each cross section representing winds in knots as measured at the plant meteorological station 200 ft above ground on the plant structure.

Various flight patterns were investigated. The first flight on 7 December 1970, from 0815 to 1030, was basically an instrument test in conjunction with the work of Whalen (6). The data, when plotted in cross sections (Figs. 9 and 10) seemed to support the initial conviction that there was a significant effect on the local atmosphere near the source.

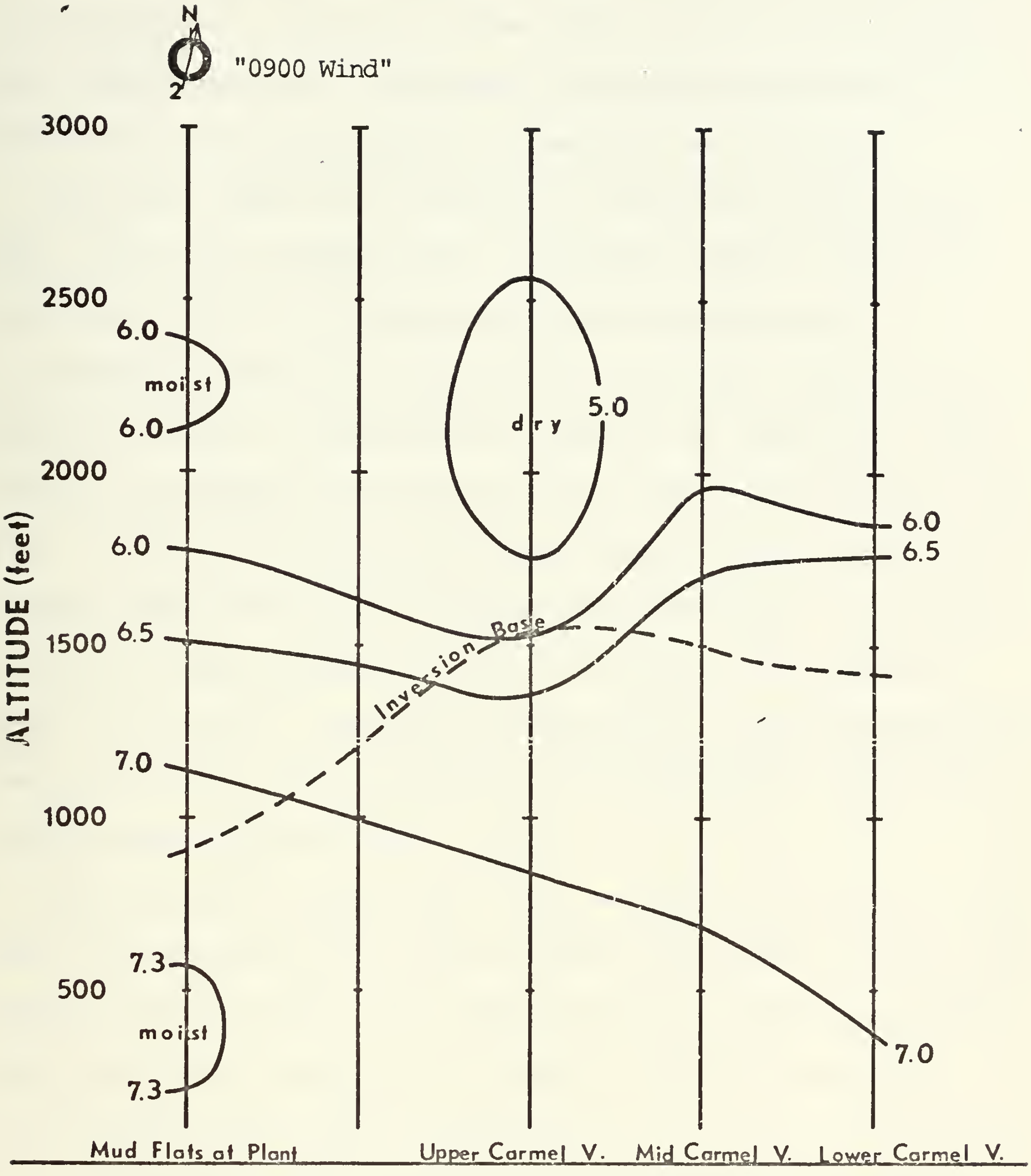
Four soundings were taken, three in Carmel Valley and a fourth at Moss Landing over mud flats just north of the plant. The lower Carmel Valley sounding was taken over a golf course near the beach front and can be considered a coastal sounding similar to the Moss Landing sounding. It is interesting to note that, though similar in location in relation to the ocean and prevailing winds, both the moisture and temperature structures are strikingly different.

The lower valley sounding shows a relatively dry area from 900 to 1400 ft, a relatively cold area from 1950 to 2250 ft, and an inversion base at about 1400 ft. In the plant area the inversion is near 850 ft. A relatively warm area exists from 2050 to 2500 ft and, in general, the whole column is more moist by about 0.5g/kg in mixing ratio. The inversion in the plant area is just above stack level (500 ft).



TEMP (°C) 7 DECEMBER 1970

FIGURE 9



MIXING RATIO (g/kg) 7 DECEMBER 1970

FIGURE 10

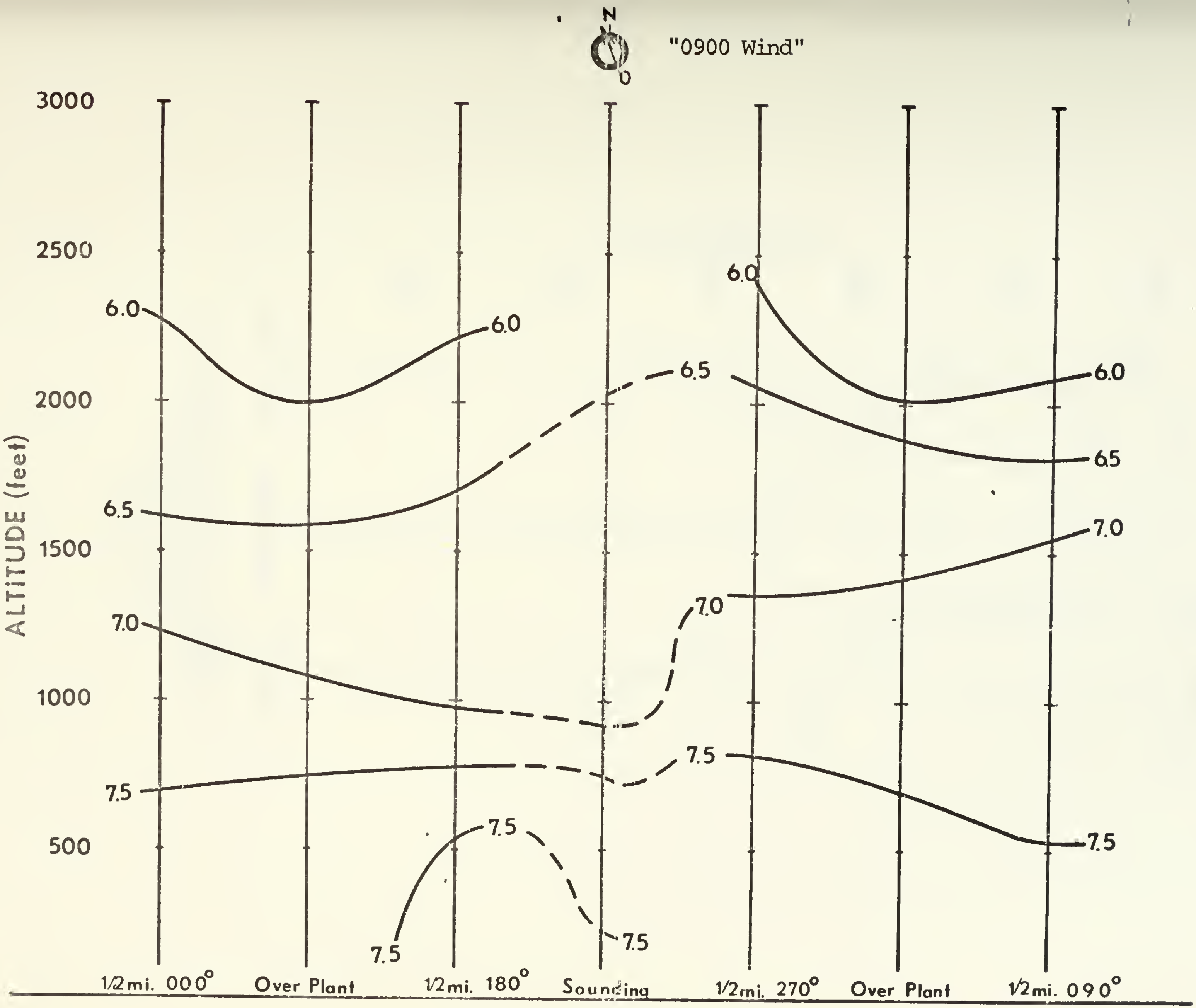
At the observation time a frontal system was located about 400 miles to the northwest. The frontal system passed through the area 43 hours after observation time. Heat release at the time averaged about 1750 x 10^6 BTU/hr with a fuel consumption of about 65% of full load.

The second flight, on 22 January 1971, from 0815 to 1000, was the final flight test in Whalen's work. Commencing with this flight the instrument mounted in its bracket became fully operational.

Because the operational capability of the equipment prior to take-off was not known, no prearranged data network was agreed upon. After take-off the equipment was operating and a circular flight plan at about one-half mile range from the power plant stacks was agreed upon, plus a sounding again over the mud flat area north of the plant. Data points on cardinal compass headings relative to the stacks were chosen and plotted up to 3000 ft. Additional data points were sampled directly over the plant at 2000, 2500, and 3000 ft. North/south and east/west cross sections were constructed (Figs. 11-13).

From the data it appeared that there was little effect from the waste heat on the atmosphere, but moisture content modification was very evident directly over the stacks. The effect of moisture appeared negligible at the one-half mile circle, but this cannot be a concrete conclusion without data points further from the plant.

At observation time a strong ridge was penetrating into northern California, bringing light offshore-flowing currents along the coast. The day was cloudless with a very low surface inversion at the plant sight (200-250 ft, i.e., below stack level). Above the inversion relative calm persisted with slight indications of a local offshore flow from time to time.

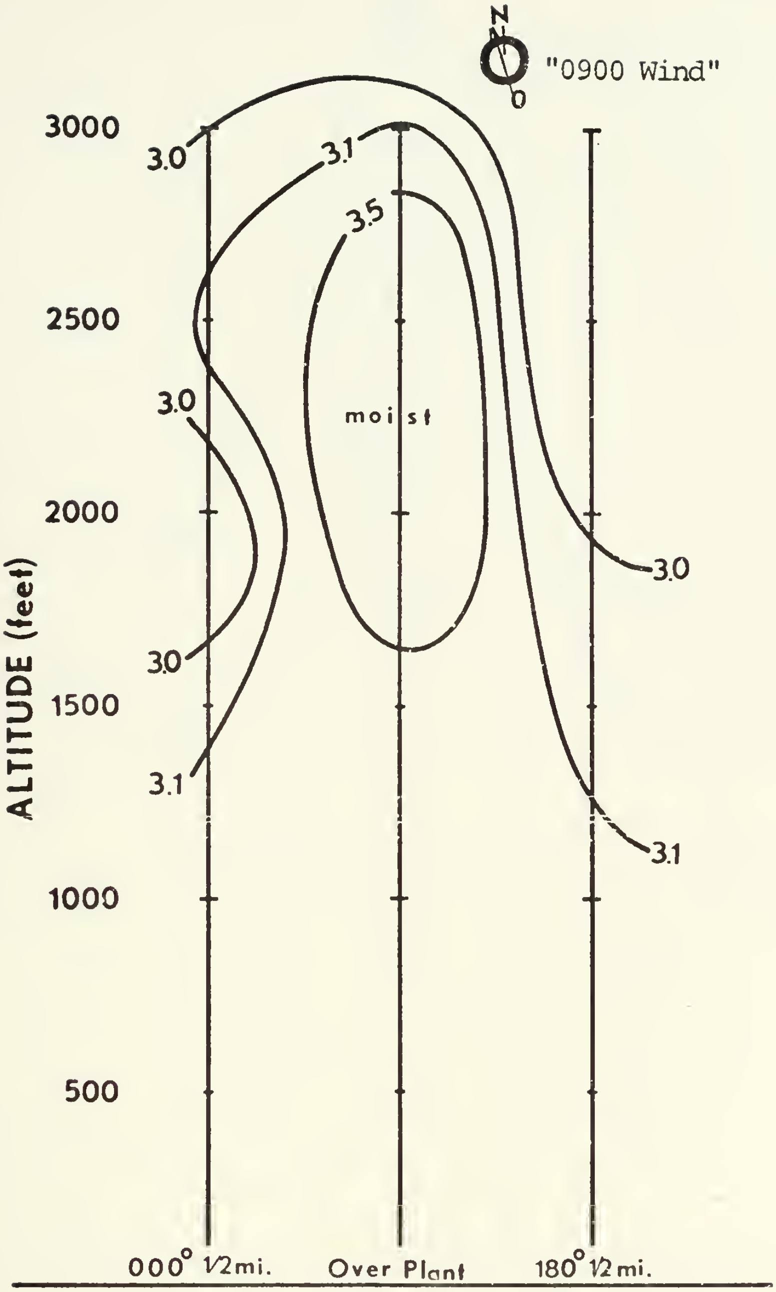


TEMP (°C) 22 JANUARY 1971

NORTH/SOUTH CROSS SECTION THROUGH PLANT

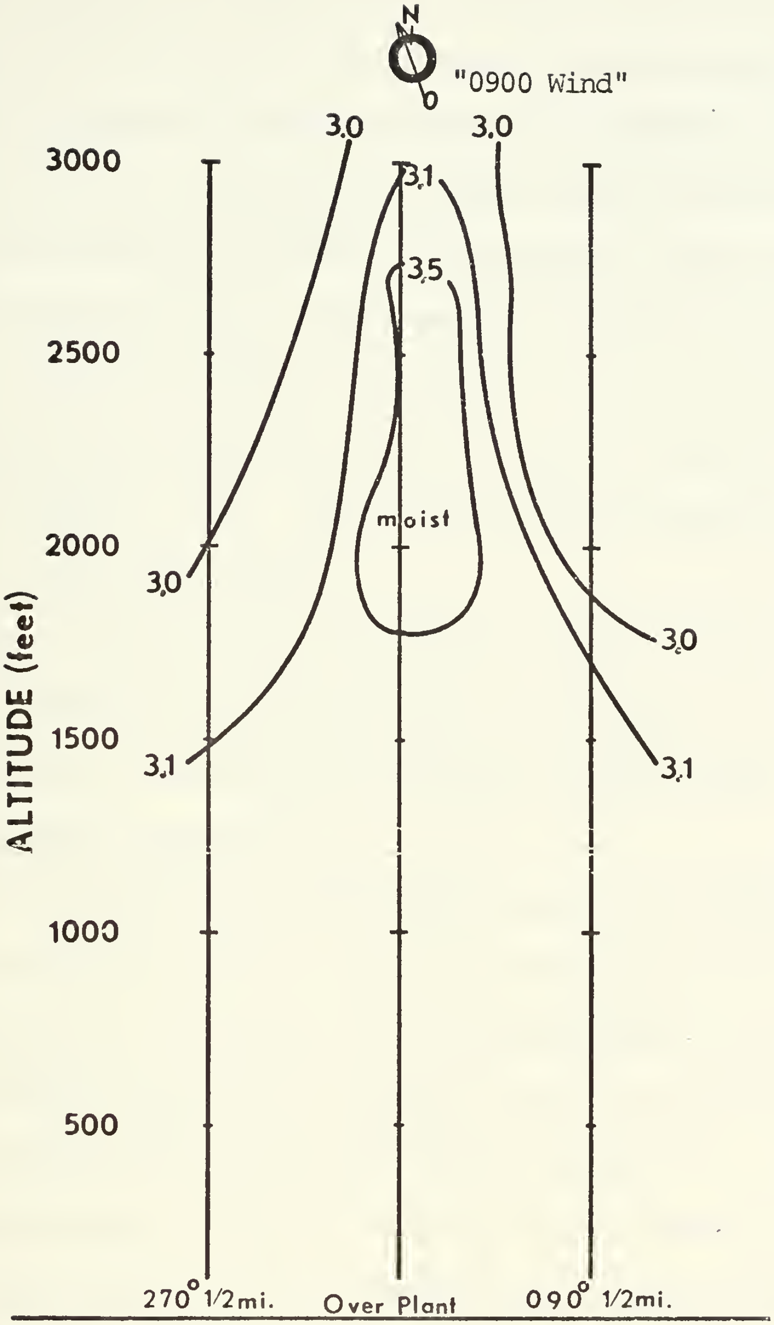
WEST/EAST CROSS SECTION THROUGH PLANT

FIGURE 11



MIXING RATIO (g/kg) 22 JANUARY 1971
NORTH/SOUTH CROSS SECTION
THROUGH PLANT

FIGURE 12



MIXING RATIO (g/kg) 22 JANUARY 1971
WEST/EAST CROSS SECTION
THROUGH PLANT

FIGURE 13

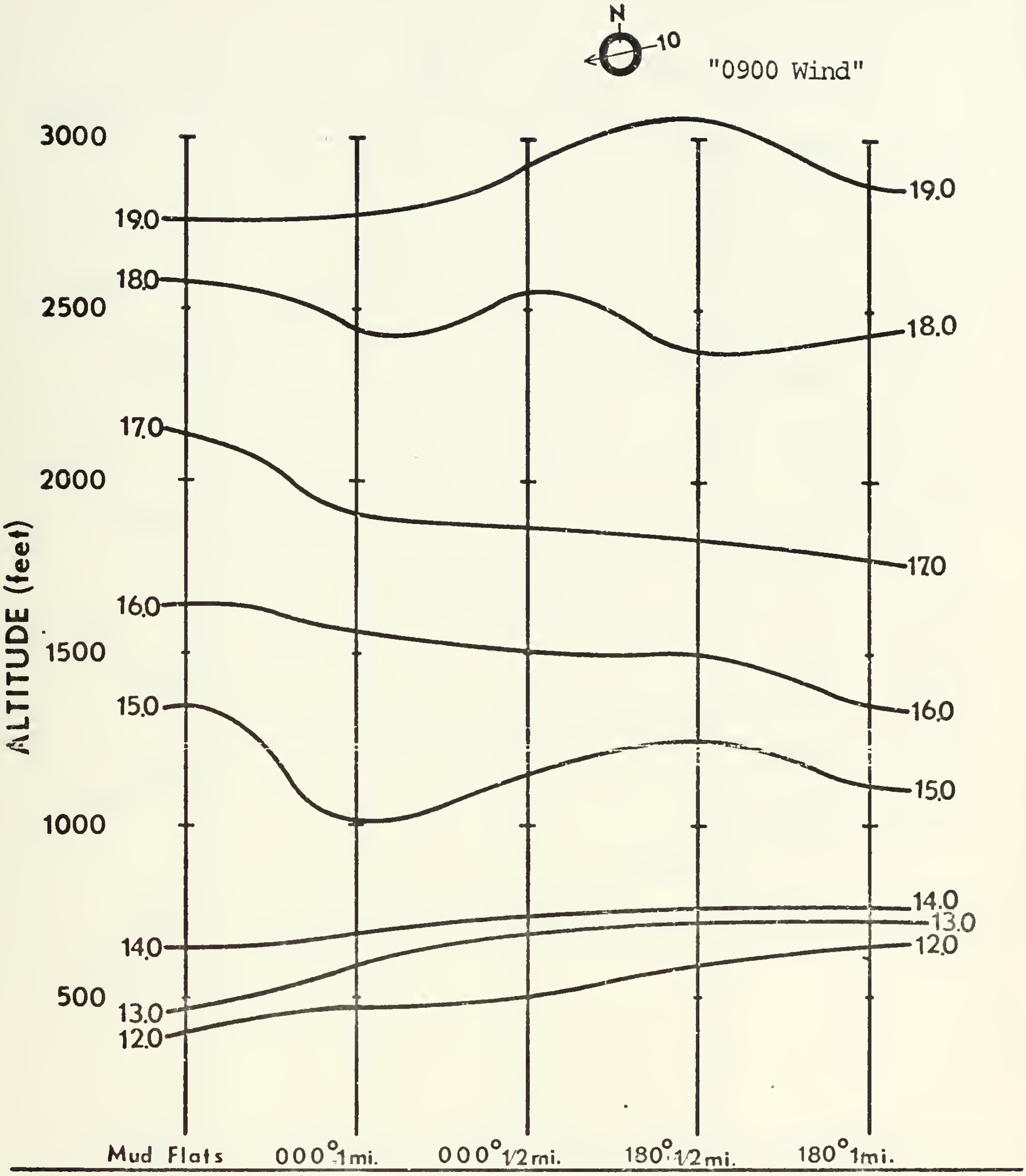
Since there was no visible plume of moisture from the stacks, an attempt was made to trace the stack gases. Several passes were made at 2000, 2500, and 3000 ft for this purpose. No temperature indications were received, but in the 2000- and 2500-ft passes strong moisture indications were received. At 3000 ft no evidence of stack gases could be obtained indicating that a rapid dissipation process was functioning in the 500-ft layer from 2500- to 3000-ft.

Plant waste heat output ranged from 1500 x 10^6 BTU/hr at 0800 to 1160 x 10^6 BTU/hr at 1000. Plant fuel consumption ranged from 55% to 43% of full load respectively.

During the third flight, on 29 January 1971, from 0815 to 1030, prevailing conditions were very similar to 22 January. A very low-level inversion existed with associated low-level offshore breeze. It was a clear, cloudless, and warm day.

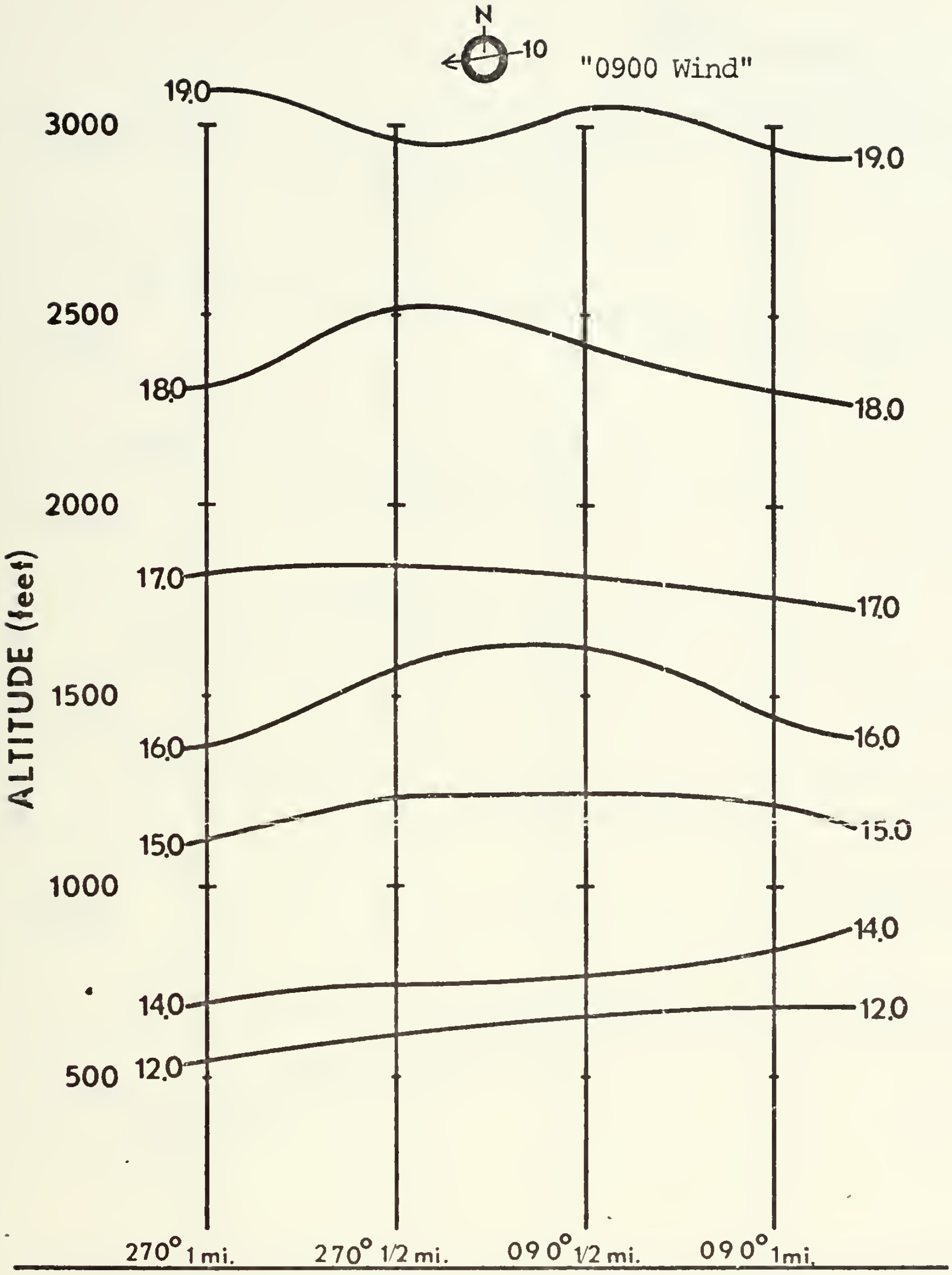
A pattern similar to 22 January was flown, but in addition to the one-half mile circular pattern, a one-mile circle was also flown. The sounding over the mud flats just north of the plant was again included.

The resultant north/south temperature (Fig. 14) and mixing ratio (Fig. 16) cross sections were again fairly nondescript. The east/west cross sections (Figs. 15 and 17) showed a slight upward bow of isopleths between about 1000 and 1800 ft. Pacific Gas and Electric meteorologists had reported evidence of an updraft in the plant area on occasion. They attributed it to radiated heat loss from the machinery causing a very localized low level unstable area in the plant vicinity. It appears that this phenomenon was occurring at this time, picking up the low level cooler, dryer air and transporting it upward about 800 to 1000 ft.

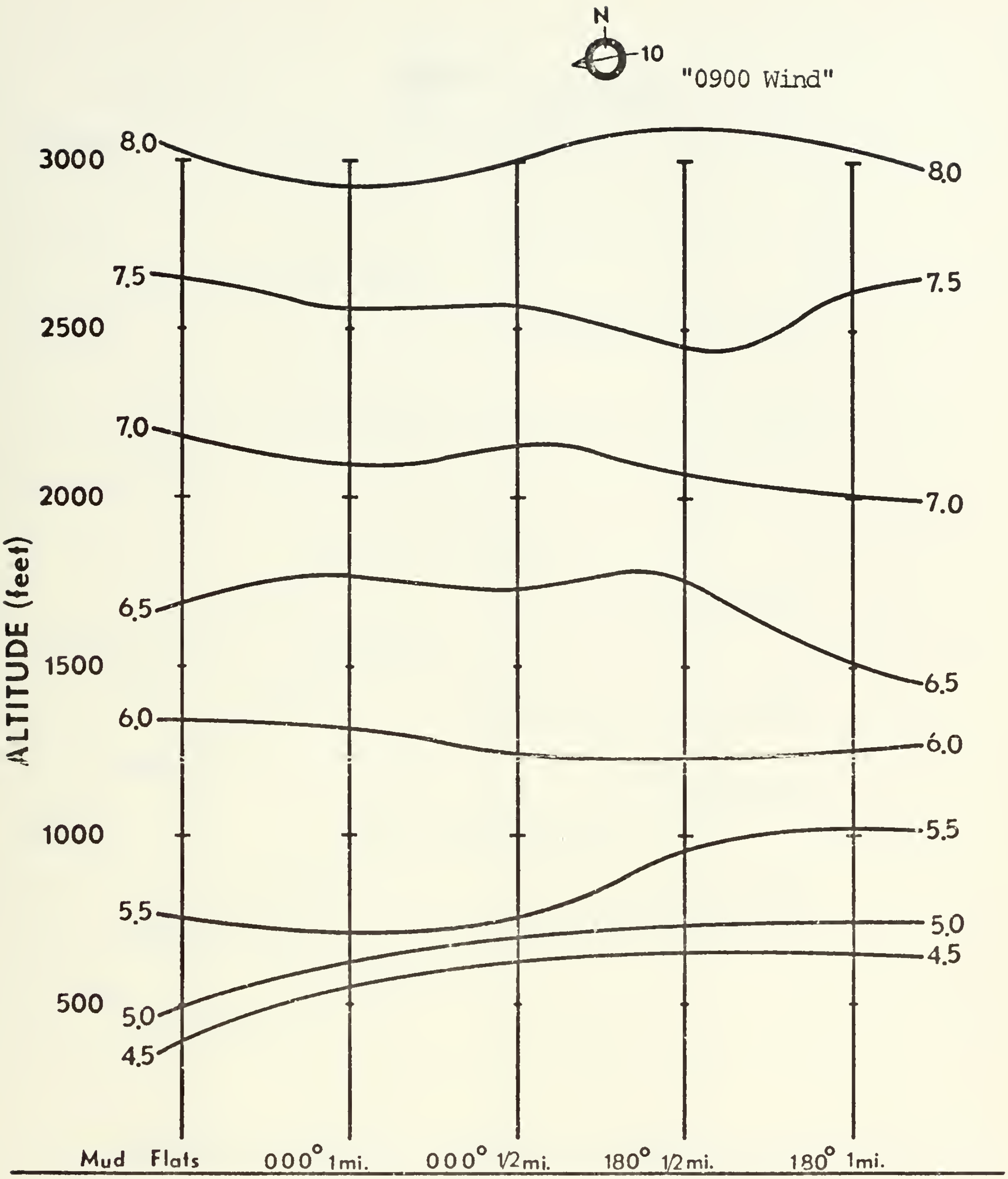


TEMP (°C) 29 JANUARY 1971
NORTH/SOUTH CROSS SECTION

FIGURE 14

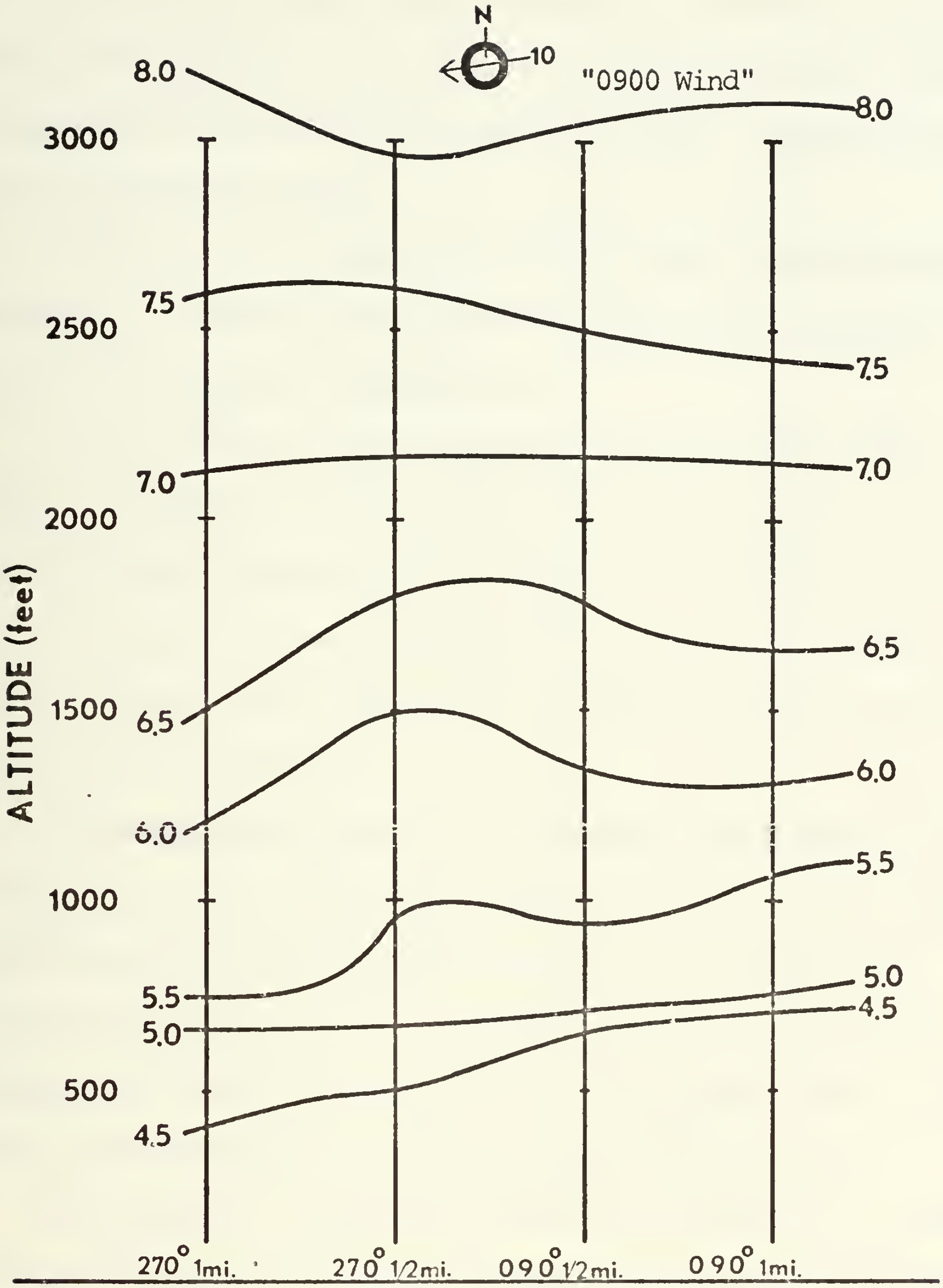


TEMP (°C) 29 JANUARY 1971
WEST/EAST CROSS SECTION
FIGURE 15



MIXING RATIO (g/kg) 29 JANUARY 1971
NORTH/SOUTH CROSS SECTION

FIGURE 16



MIXING RATIO (g/kg) 29 JANUARY 1971
EAST/WEST CROSS SECTION
FIGURE 17

That this picture is more pronounced in the east/west field is probably due to the offshore breeze present in the lower levels. This would cause vertical stratification in the east/west plane, tending to exclude evidence in the north/south plane.

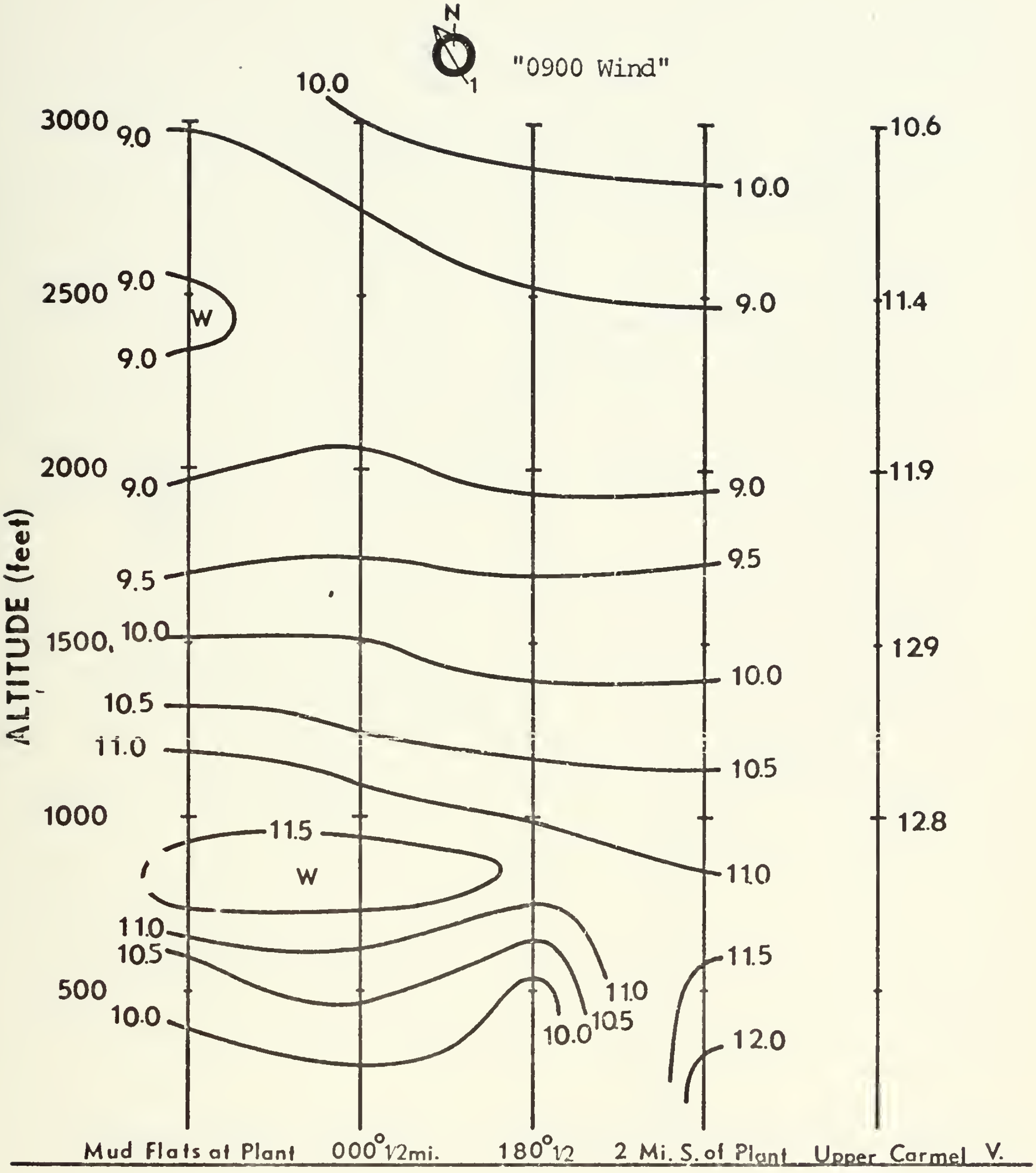
Plant waste heat during the sounding period ranged from 900 x 10^6 BTU/hr to 830 x 10^6 BTU/hr which represented plant fuel consumption of 36% to 31% of full load capacity respectively.

A third pattern of this type was flown on 1 April 1971, from 0815 to 1000. A sounding was taken over the mud flat area north of the plant. The one-half mile circular pattern was then flown followed by a sounding two miles south of the plant over an open field. An additional sounding was taken in upper Carmel Valley in an attempt to correlate a distant data point with the local conditions.

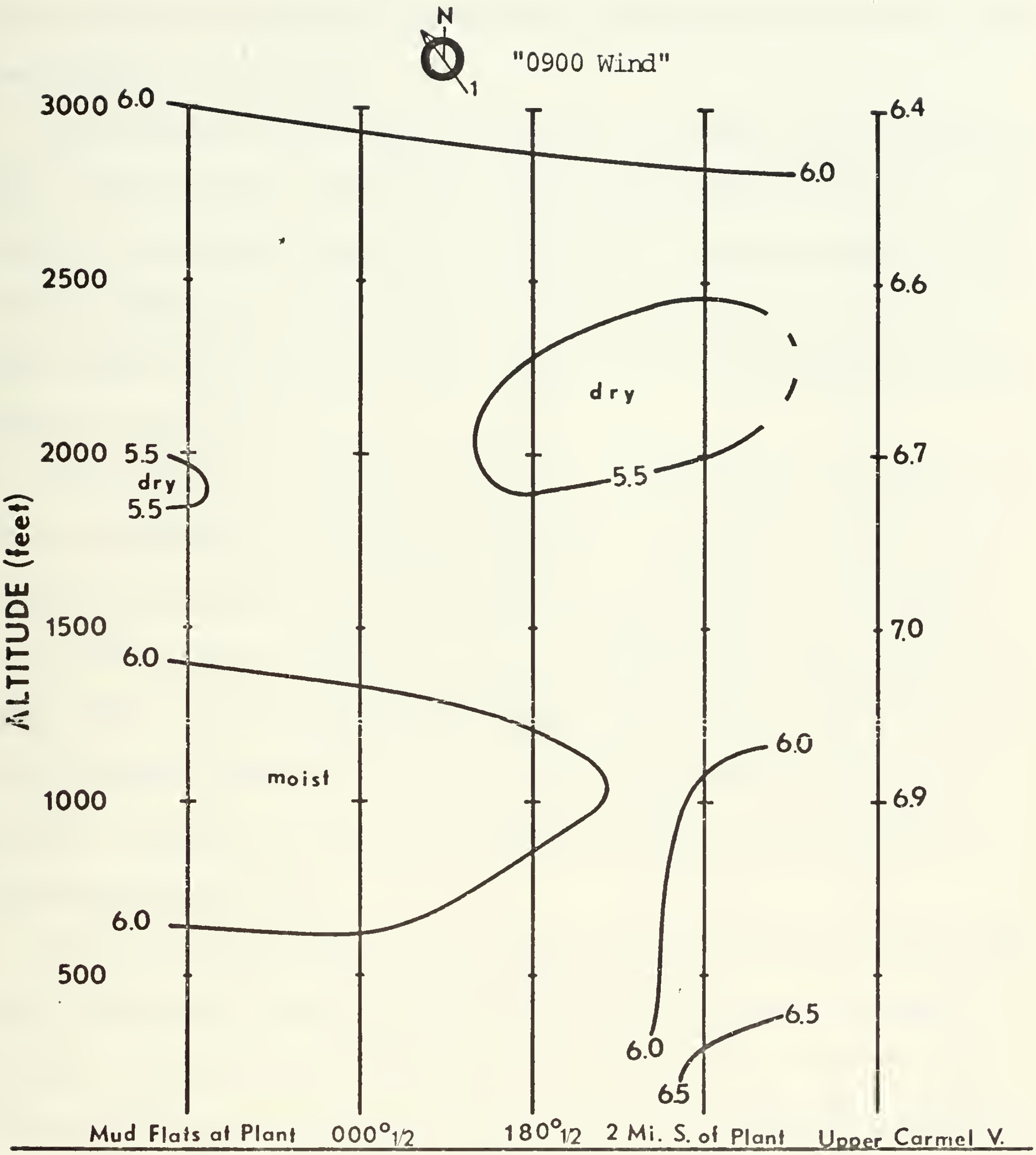
The temperature pattern (Fig. 18) shows a warm area to the north of the plant. This is not an unreasonable picture since a light offshore breeze would have been carrying stack emissions in this direction. The ambiguity of the lower portion of the sounding two miles south of the plant existed because the sounding was inland one to two miles. Thus, the lower portions were being affected by low level heating from the ground.

Observing this temperature pattern one would expect to see a similar effect in moisture. This was indeed the case with a moist tongue extending off the north (Fig. 19).

Though there appears to be no noticeable effect on the inversion, it is interesting to note the apparent sensitivity of the plant emissions to even a slight breeze.



TEMP (°C) 1 APRIL 1971
NORTH/SOUTH CROSS SECTION
FIGURE 18



MIXING RATIO (g/kg) 1 APRIL 1971
NORTH/SOUTH CROSS SECTION
FIGURE 19

Plant output ranged from 1257 x 10^6 BTU/hr to 1584 x 10^6 BTU/hr during the period while fuel consumption ranged from 47% to 57% of full load capacity respectively.

The fifth and sixth flights, conducted on 6 April 1971, from 0800 to 1100, and 1 May 1971, from 0900 to 1130, were not only an integral part of this project, but were held at the request of San Jose State College. Flight patterns were thus altered to aid San Jose State's study of the wind regime in the Salinas Valley. Continuity with the primary project, however, was not lost.

The pattern consisted of a sounding at each of the following locations: five miles out in Monterey Bay; Moss Landing Beach interface adjacent to the plant; Hartnell College Farm adjacent to the Salinas, California, airport; four miles south of Soledad, California, over an open field. An additional sounding was made on 1 May 1971 adjacent to the King City, California, airport. The 6 April cross section thus spanned a distance of 43 miles and the 1 May cross section spanned approximately 60 miles.

These two days proved to be a unique pair synoptically in that both sets of data were taken approximately nine hours prior to a frontal passage. Cloud coverage consisted of overcast with low broken clouds close to the coast but clearer inland. The low clouds were somewhat more dense on 1 May, limiting the over-bay and beach interface soundings to about 2000 ft. An inversion was present on 6 April but was not evident in the 1 May data up to the heights sounded. It is probable a localized inversion was present along the coast on 1 May as evidenced by the low overcast in that area, but due to flight safety requirements the sounding was terminated at the cloud base.

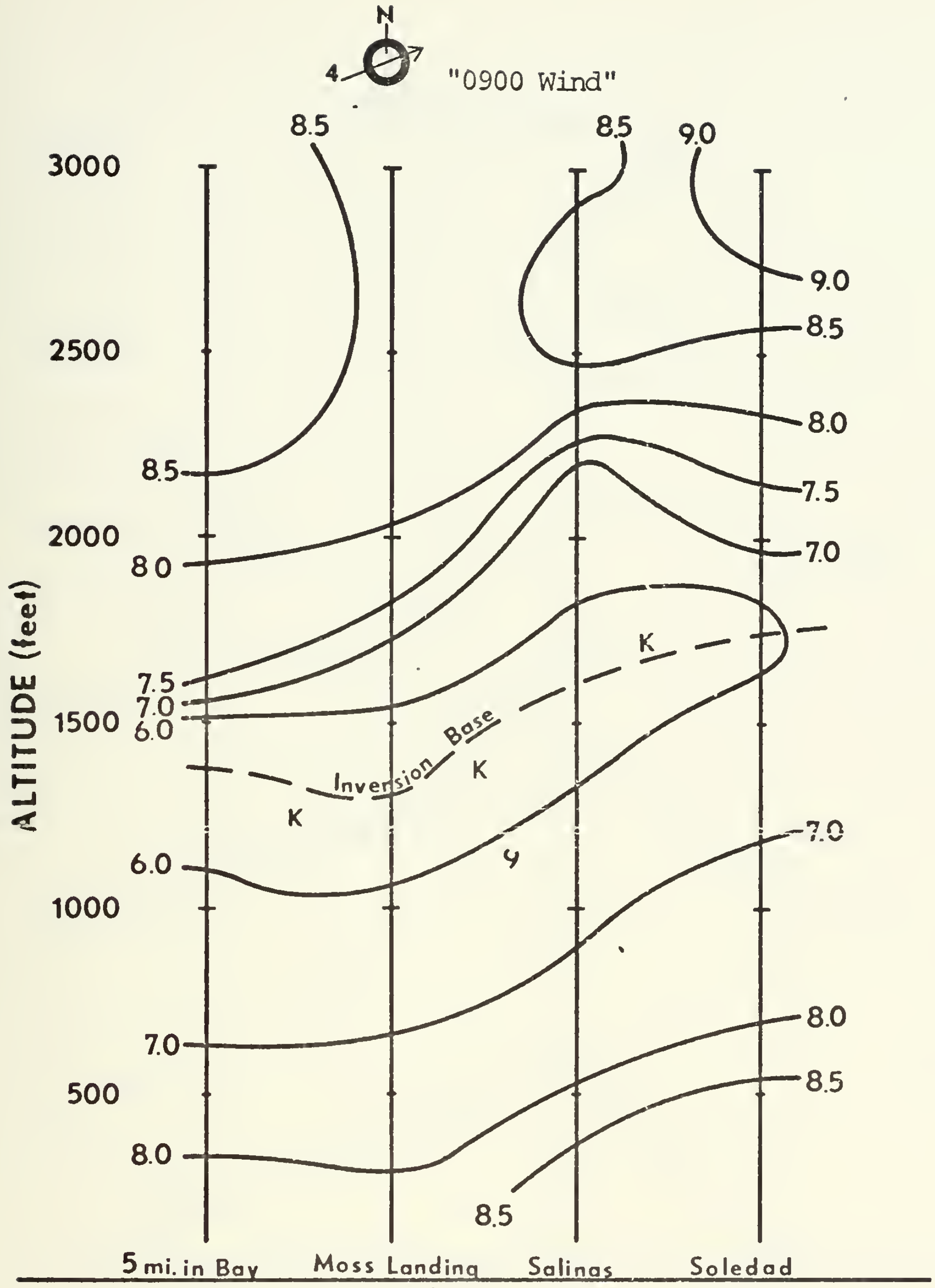
The isotherm and mixing ratio patterns (Figs. 20-23) for the two days are strikingly different. On 6 April the inversion appears to be lowered in the vicinity of the power plant about 100 ft from its overwater height. It then begins to rise as it moves inland. The intensity of the inversion as indicated by temperature gradients appears little affected.

There can be two processes at work in this case. Either the waste heat and exhausted moisture are combining in such a way as to slightly lower the inversion or, since the sounding was taken about one-half mile inland, there is some form of lee wave influence over the beach front dunes. Since there was only a slight sea breeze of less than five knots at the time and the beach structure is fairly low and gentle, the lee wave effect can probably be ruled out.

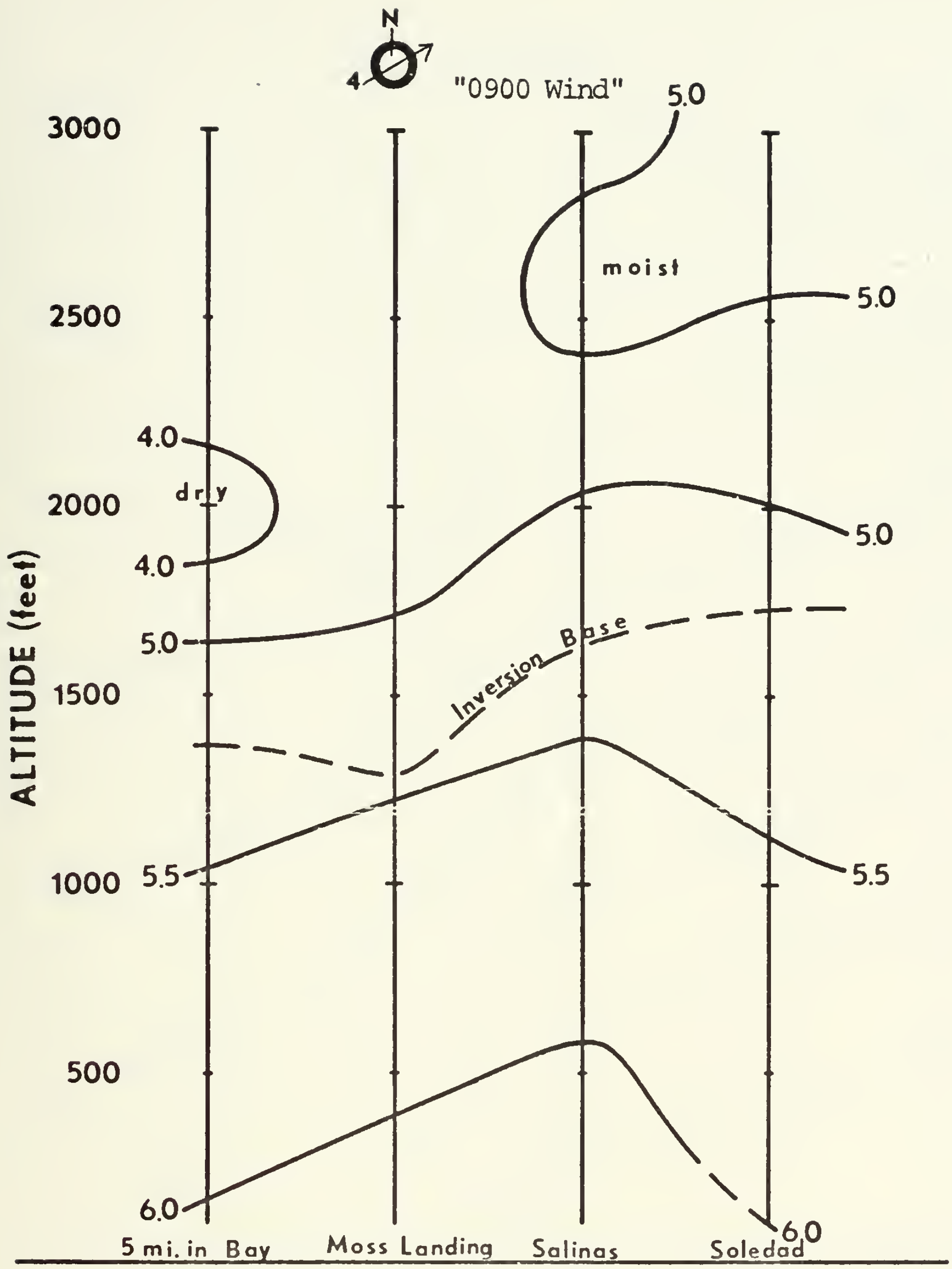
The moisture picture for 6 April shows little in the way of distintive patterns, thus little can be concluded about the effect on the atmosphere by the plant.

The 1 May temperature data shows a general rise in contours inland. This is in general agreement with the structure found by Edinger (1963) (7) in his investigation of marine air penetration into the agricultural Santa Clara River Valley, located just north of Burbank, California. Based on this, one can say that the pattern is not locally produced, but is the general scheme of marine air penetration along the west coast.

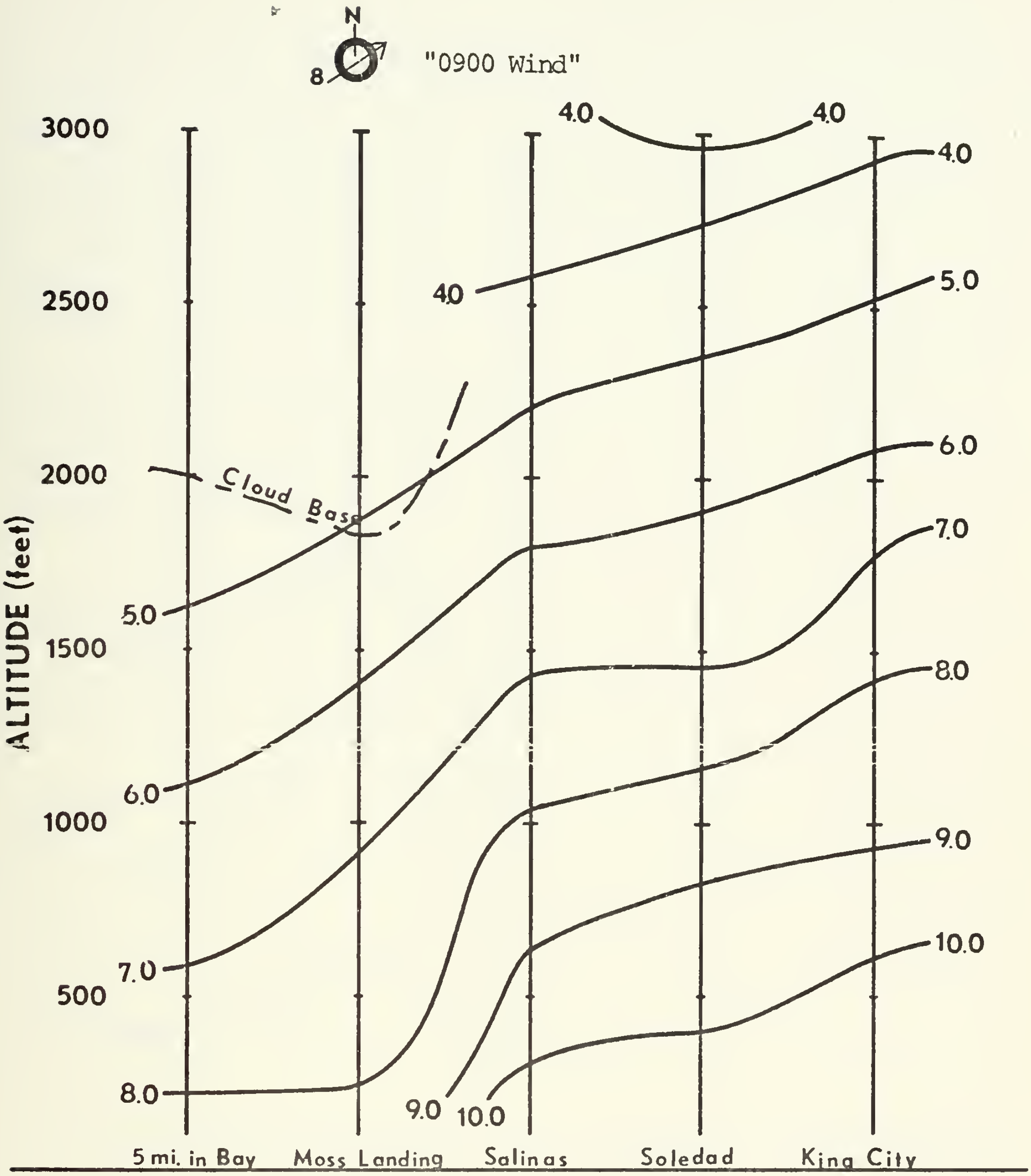
In direct contrast to the moisture picture of 6 April, that of 1 May shows a striking dome of moisture directly over Moss Landing, penetrating some 200 to 400 ft above the more distant areas. The observed cloud base also drops some 200 ft in the area indicating that the condensed moisture from the plant is being trapped below the cloud bank. This also compares



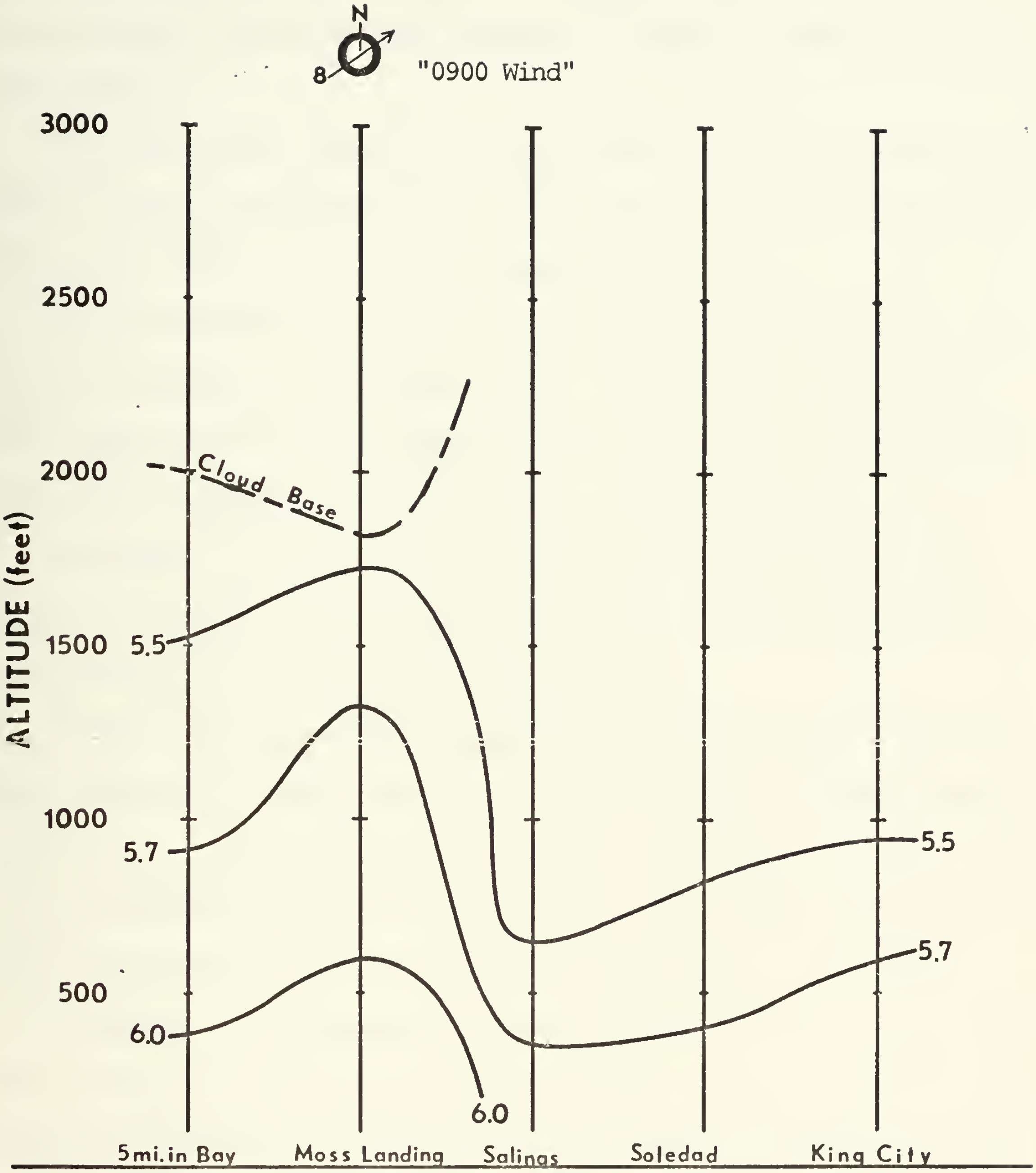
TEMP (°C) 6 APRIL 1971
CROSS SECTION INTO SALINAS VALLEY
FIGURE 20



MIXING RATIO (g/kg) 6 APRIL 1971
CROSS SECTION INTO SALINAS VALLEY
FIGURE 21



TEMP (°C) 1 MAY 1971
CROSS SECTION INTO SALINAS VALLEY
FIGURE 22



MIXING RATIO (g/kg) 1 MAY 1971
CROSS SECTION INTO SALINAS VALLEY
FIGURE 23

very favorably with the 7 December 1970 data in which the inversion base was lower and the moisture content was higher in the column above Moss Landing.

Plant waste heat output on 6 April ranged from 541 x 10^6 BTU/hr at 0800 to 1434 x 10^6 BTU/hr at 1000. Plant fuel consumption ranged from 20% to 54% of full load capacity respectively.

Boiler duct work modifications on 1 May resulted in an outage of one of the two main units. Thus waste heat figures were very low for the day, ranging from 339 x 10^6 BTU/hr at 0800 to 718 x 10^6 BTU/hr at 1100. Plant fuel consumption ranged from 12% to 26% of full load.

The seventh flight, flown on 9 June 1971, from 0830 to 0915, was unique, not from the data standpoint, but from the highly localized phenomena which occurred during data collection.

Flight conditions were marginal with ceilings at 500 ft lowering to 300 ft along the coast. Receipt of a special flight clearance allowed the trip to the Moss Landing area. There a large hole was found to exist in the otherwise dense fog and low overcast. The radius was estimated to be one-half to one mile with the plant approximately at the center.

A sounding was immediately initiated over the mud flats just north of the plant which yielded data to 2600 ft before the cloud base was entered. Offshore a sounding was attempted at about one-half to one mile into the bay. This sounding was terminated at 500 ft due to the fog and overcast. It was then observed that the large opening sampled a few minutes earlier had completely filled, with cloud bases down to 200-300 ft. A third sounding attempted inland from the plant was again terminated at 500 ft for the above reasons.

Plotted in cross section (Figs. 24 and 25) the data itself shows little. The visual phenomena sighted by the entire helicopter crew do, however, yield valuable qualitative data. The presence of the open area is evidence of an area of very localized warming or moisture reduction. That it disappeared so rapidly is evidence of an extremely localized addition of moisture or cooling, such that the dew point was reached simultaneously throughout the area. The result was a rapid filling of the area with fog.

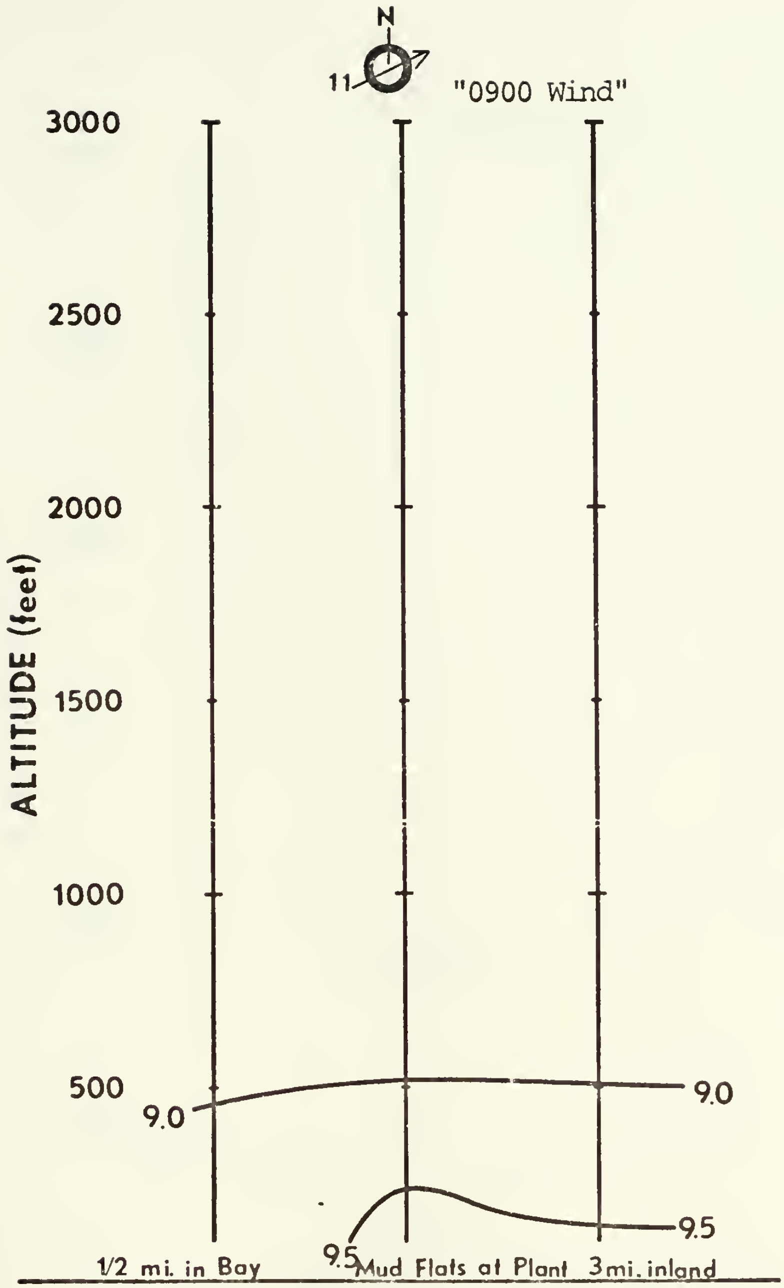
Because the plant was at the approximate center of the opening, one could easily assume that it must have in some way played a vital role in the delicate balance of atmospheric conditions observed. The cross section indicates what might have been a slight dome of warm air in the plant area at the time of the sounding.

A return sounding after the filling of the hole was not attempted due to flight safety considerations; thus it is only speculation as to the phenomena which occurred permitting the fog to form.

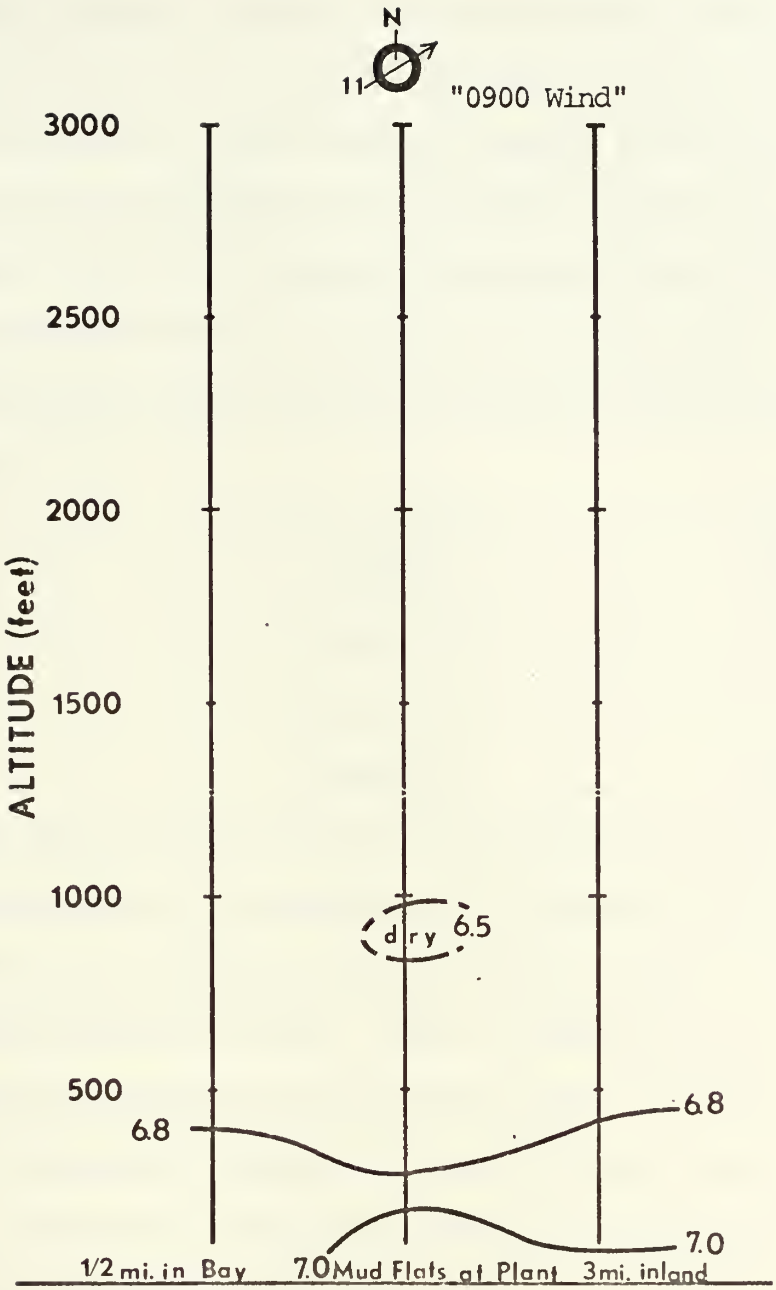
A change in firing rate would have the following effects:

a. Since the basic premise of a steam turbo-electric power plant is energy flow at constant temperatures, a reduction in firing rate would not change the amount of heat lost as radiation through the insulation on pipes and machinery to the atmosphere at low levels. A reduction in firing rate reduces only stack emitted quantities. Thus less moisture and heat enter the atmosphere at the 500 ft plus level.

b. An increase in firing rate increases the heat and moisture addition at 500 ft and above, but for reasons stated in (a), has no effect below this level if the possibility of downward diffusion is discounted.



TEMP (°C) 9 JUNE 1971
EAST/WEST CROSS SECTION
FIGURE 24



MIXING RATIO (g/kg) 9 JUNE 1971
EAST/WEST CROSS SECTION
FIGURE 25

It is theorized that conditions above stack level were such that the low level buoyancy, caused by radiated heat loss, was able to break through and rise to 2600 ft, forming the hole. Further, a change in firing rate either up or down resulted in enough stabilization above 500 ft that the low level buoyancy was not enough to break through and the fog re-formed. There was no apparent immediate effect of rotor downwash from the helicopter during the flight within the open area.

Plant waste heat output and fuel consumption during the flight were as follows:

	Fuel Consumption ft^3/hr	Waste Heat BTU/hr
0800	7647×10^3	1052×10^6
0900	8133×10^3	1125×10^6
0100	7685×10^3	1055×10^6

As indicated the fuel consumption and the waste heat output increased between 0800 and 0900. The sounding in the open area occurred at approximately 0830 and the area was completely filled by 0840. The third and final sounding occurred at 0850. Thus the formation of the fog occurred during an hour of relatively higher firing rates, waste heat and moisture emission. This seems to support the hypothesis that due to a firing rate increase a more intense inversion was formed and the weak low-level buoyancy was incapable of breaking through.

Temperature sensing equipment located on the plant structure is monitored every eight seconds by the plant's computer which also monitors many other plant operations, and is averaged each hour. It is interesting to note that the 0800, 0900, and 1000 readings were as follows:

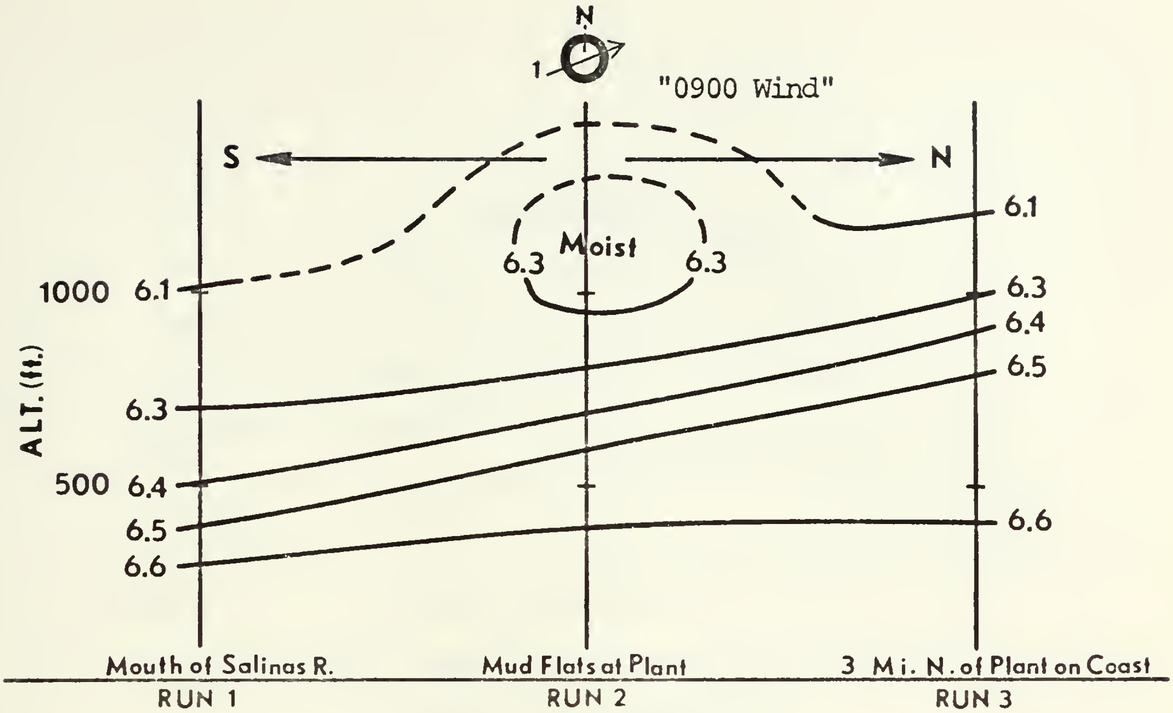
	Dry Bulb (°F)	Dew Point (°F)
0800	51	49
0900	51	49
1000	51	50

Since the hole filled late in the hour of 0800-0900, it did not have enough influence to alter upward the 0900 hourly average. It did, however, alter the 1000 average as shown. The equipment is located at approximately 185 ft above ground and right at the base of the observed cloud base after filling.

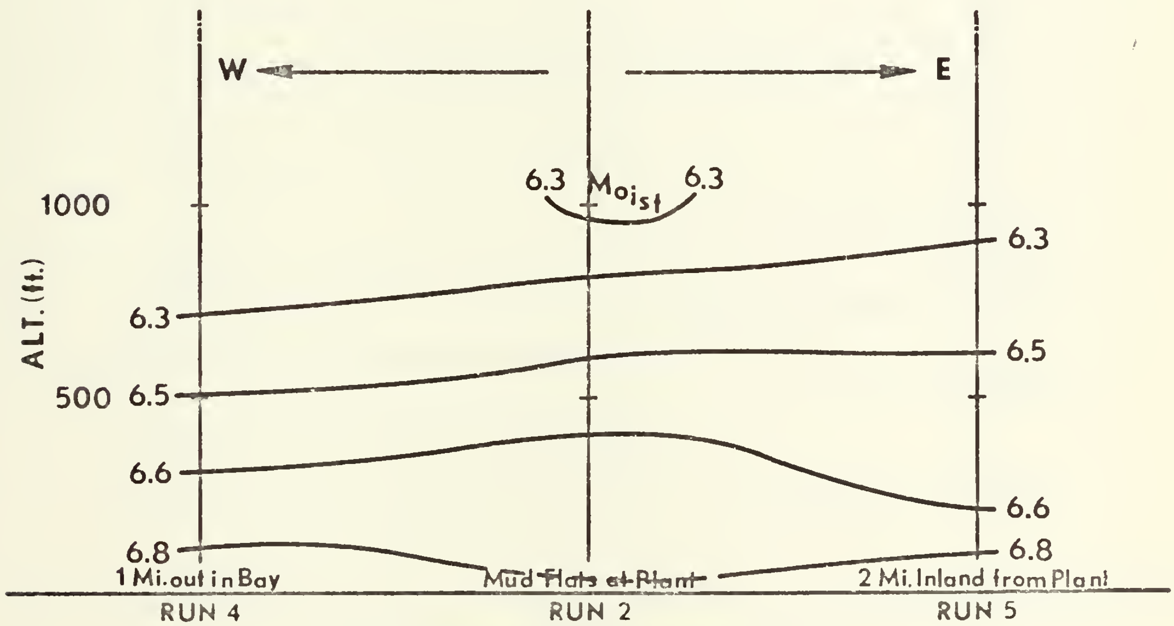
The eighth and ninth flights on 11 June, from 0830 to 1000, and 9 July, from 0800 to 1030, were similar in that a standardized sounding pattern was established (Fig. 8). The one overbay sounding on each day was assumed representative of all local overbay atmospheric conditions. Thus with seven sounding points, five cross sections could be constructed, three normal to the beach and two parallel to the beach.

On 11 June a low overcast existed throughout the area with cloud bases near 1000 ft. Both the cross sections normal to the coast (east/west) and the coastal cross section (north/south) (Fig. 26) through the power plant show a relative warm area situated over the plant just below the cloud base. In the moisture cross section (Fig. 27) a similar pattern appears.

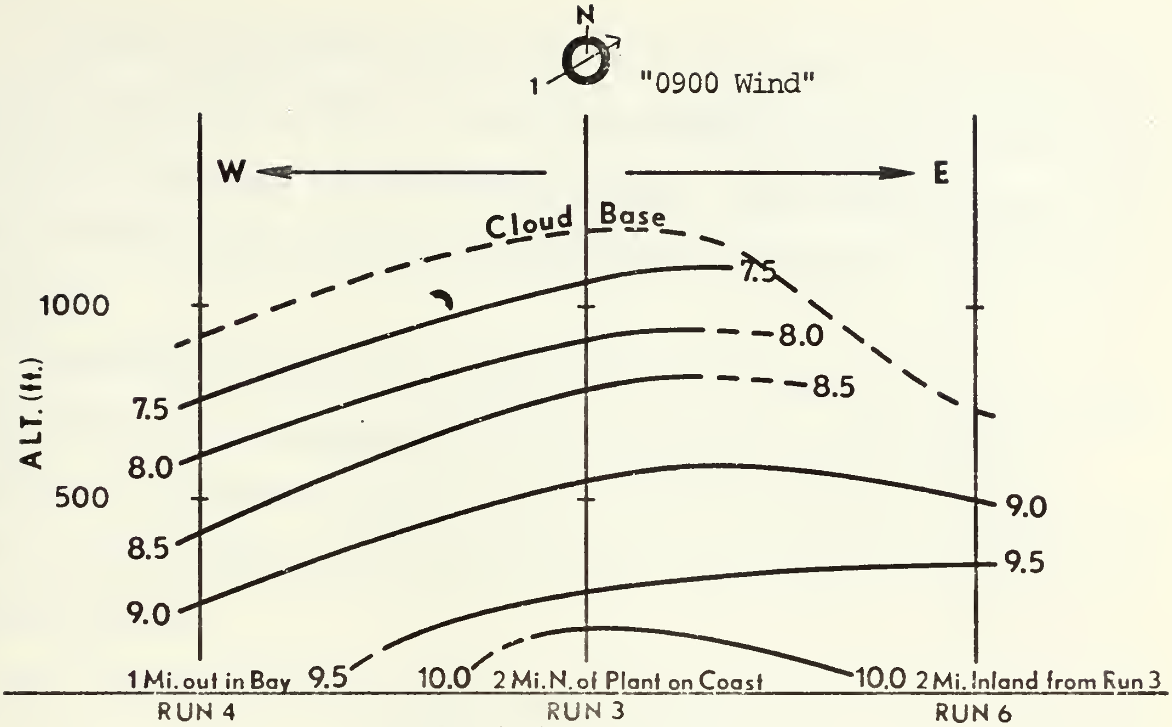
In the north/south cross section one notes an increase in the altitude of the cloud base from south to north along the coast. Though it may be directly related to the project, it is more probable that a terrain effect was in evidence. The beachfront at the northern-most sounding was quite rugged and heavily duned, while the other two soundings were over quite low, open, and flat terrain. Also a zealous pilot may have been "looking for a hole" to gain that extra 100-200 ft.



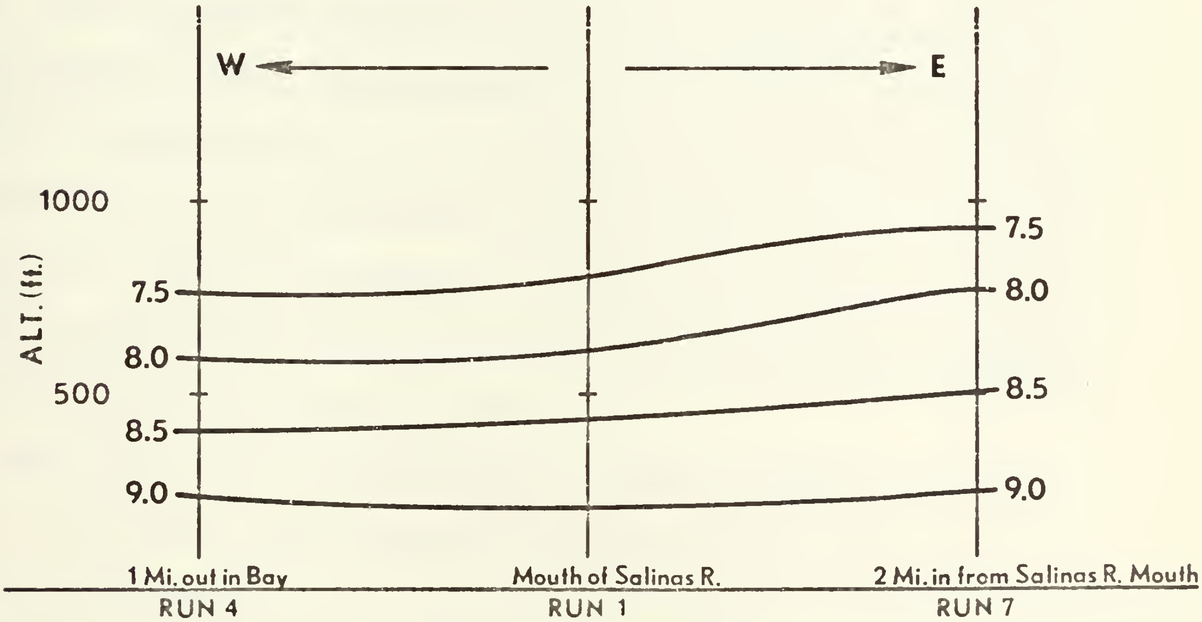
MIXING RATIO (g/kg) 11 JUNE 1971
NORTH/SOUTH CROSS SECTION ALONG COAST



MIXING RATIO (g/kg) 11 JUNE 1971
EAST/WEST CROSS SECTION THROUGH PLANT AREA
FIGURE 26



TEMP (°C) 11 JUNE 1971
EAST/WEST CROSS SECTION NORTH OF PLANT



TEMP (°C) 11 JUNE 1971
EAST/WEST CROSS SECTION SOUTH OF PLANT
FIGURE 27

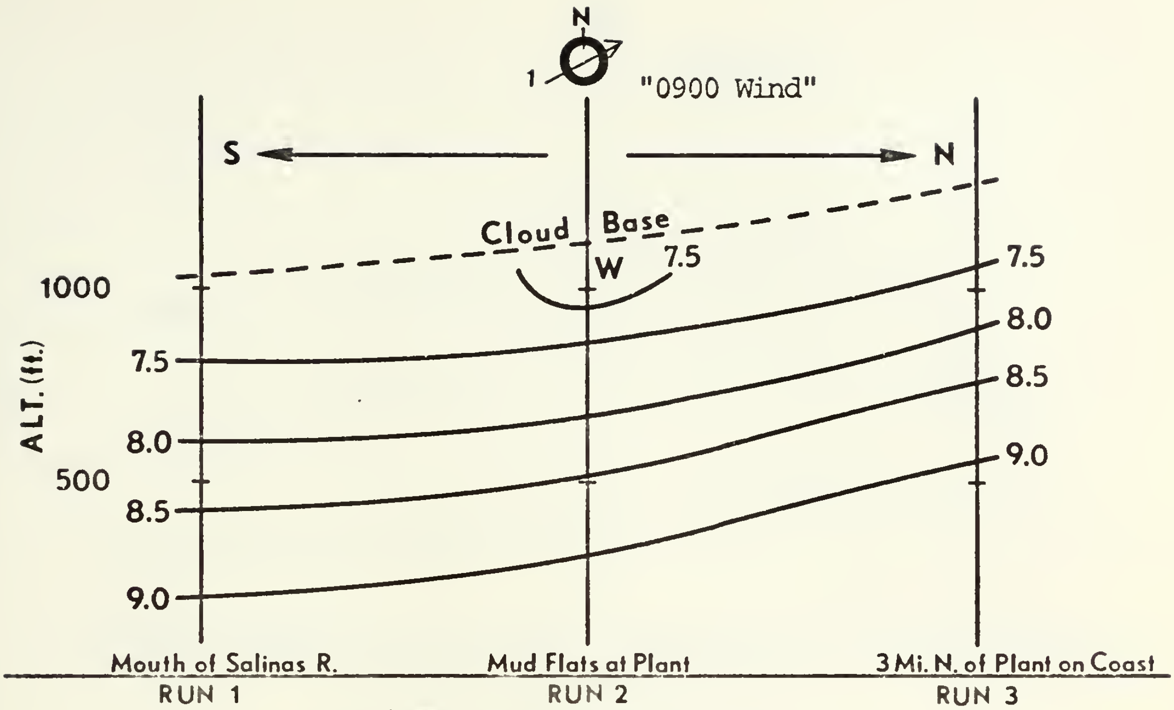
A look at the profiles (Figs. 28 and 29) north and south of the plant normal to the beach tends to confirm the terrain hypothesis. The southern profile is very flat rising slightly inland. This corresponds well with the flat open fields and low dune structure at the mouth of the Salinas River.

The profile normal to the beach north of the power plant shows a definite upward bow of isotherms indicating a possible terrain effect in progress. It should be noted that the terrain in the plant area along the coast is also relatively low and much less rugged than the area north of the power plant.

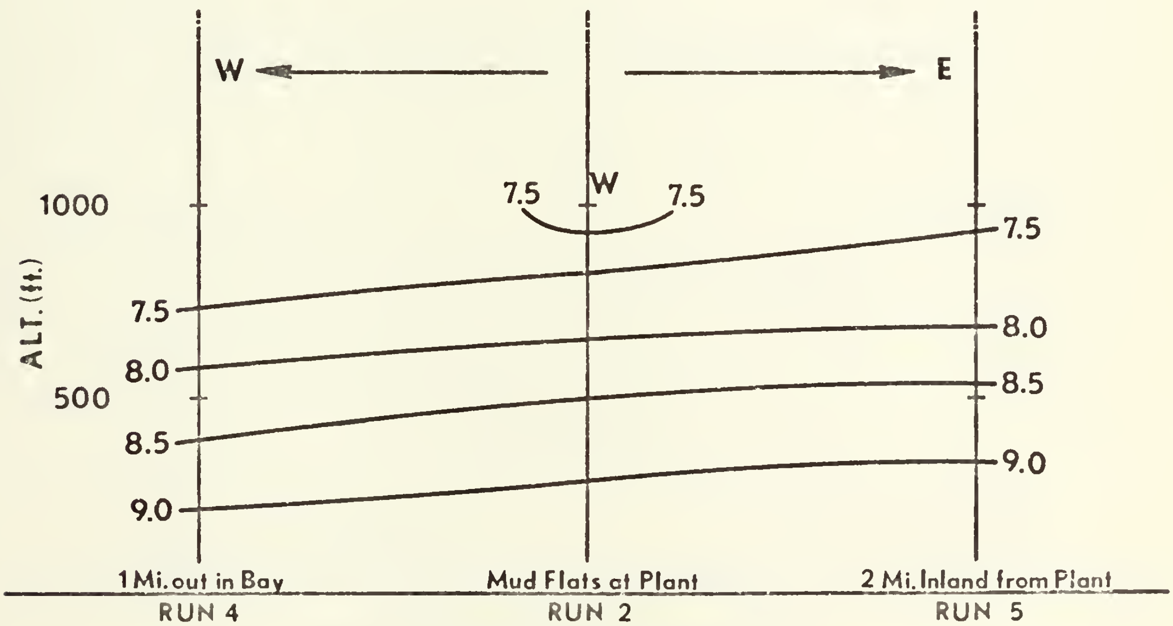
The inland north/south profile (Fig. 30) also shows a most interesting feature. During the observation period the winds ranged from one to four knots. Wind direction ranged from south southwest at 0800 to westerly at 1000. From the sounding pattern it can be determined that the northernmost sounding, inland from the mouth of the Pajaro River, is directly downwind from the plant area. In this vicinity a lowering of the cloud base some 300 ft was observed along with a moisture maximum between 600 and 700 ft. Though not conclusive in itself, it is certainly indicative that the power plant's waste heat and moisture were possibly being felt downwind as far as five miles or more.

Plant waste heat ranged from 915 x 10^6 BTU/hr at 0800 to 561 x 10^6 BTU/hr at 1000 while fuel consumption ranged from 36% to 21% of full load capacity respectively.

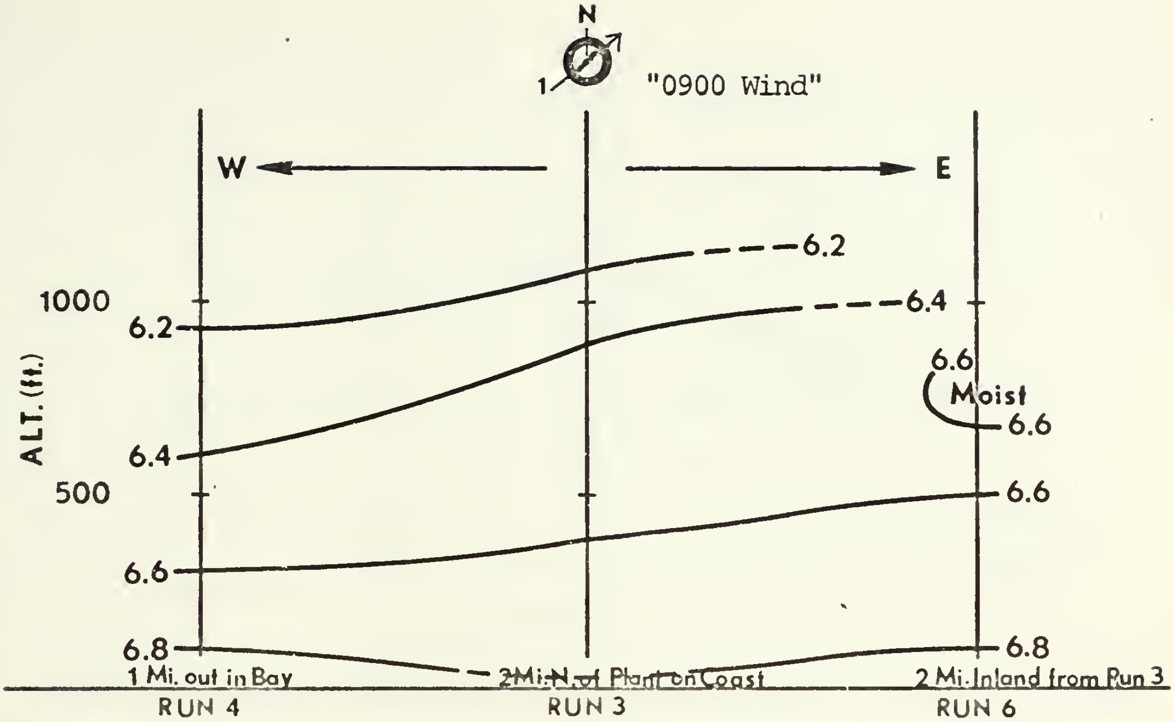
The final data collection effort on 9 July 1971 yielded a wealth of data. The day was clear and warm with a very low inversion base below 200 ft. A low band of advection fog was forming along the coast and dissipating about 50 yards inland. Winds were again light, ranging from calm to six knots and were generally from the south to southwest.



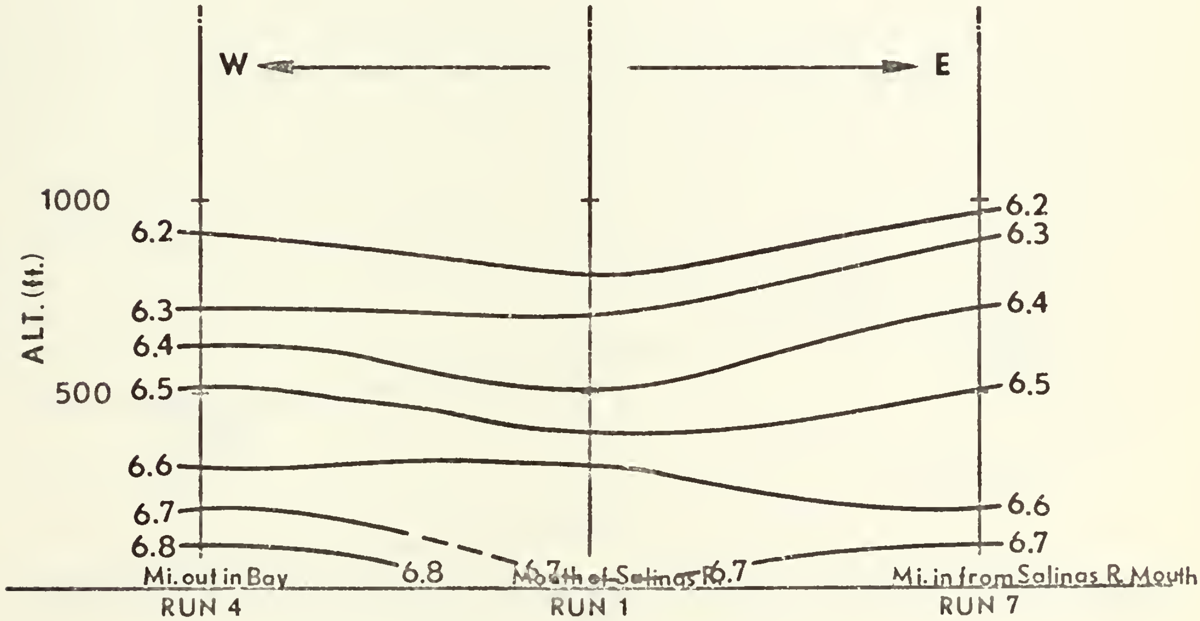
TEMP (°C) 11 JUNE 1971
NORTH/SOUTH CROSS SECTION ALONG COAST



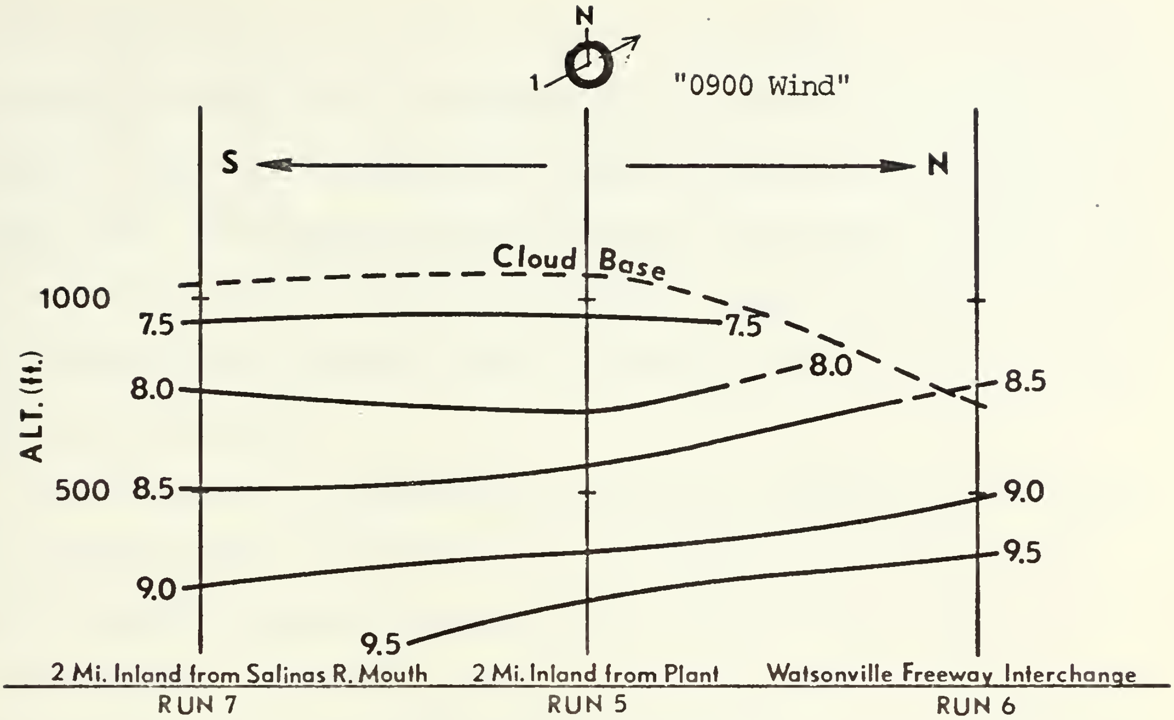
TEMP (°C) 11 JUNE 1971
EAST/WEST CROSS SECTION THROUGH PLANT
FIGURE 28



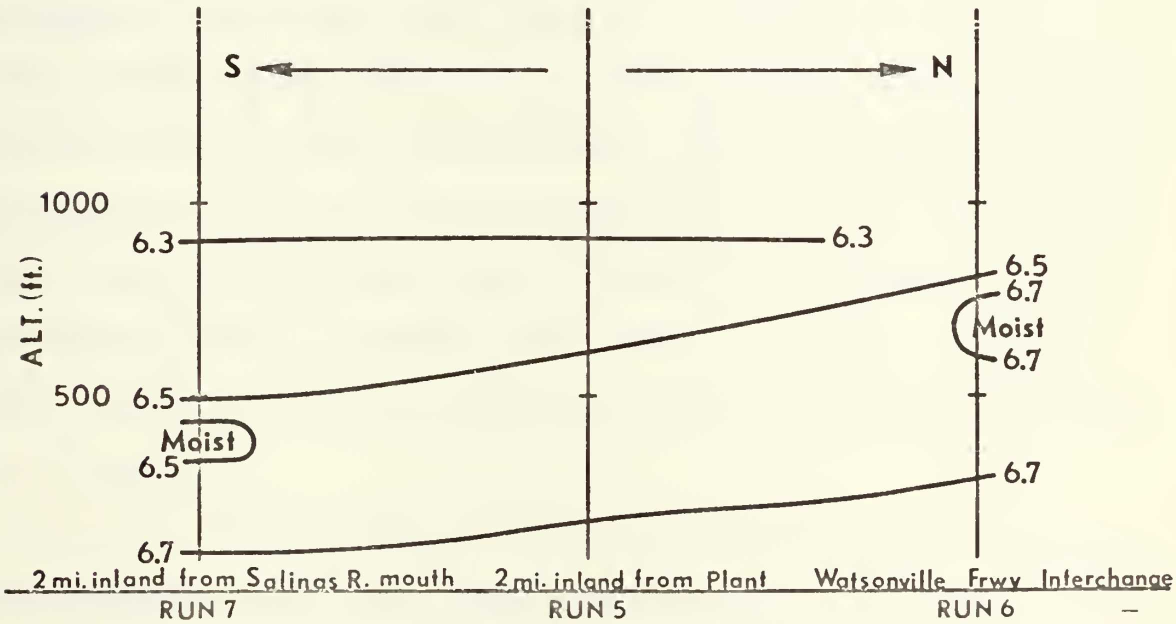
MIXING RATIO (g/kg) 11 JUNE 1971
EAST/WEST CROSS SECTION NORTH OF PLANT



MIXING RATIO (g/kg) 11 JUNE 1971
EAST/WEST CROSS SECTION SOUTH OF PLANT
FIGURE 29



TEMP (°C) 11 JUNE 1971
INLAND NORTH/SOUTH CROSS SECTION



MIXING RATIO (g/kg) 11 JUNE 1971
INLAND NORTH/SOUTH CROSS SECTION
FIGURE 30

The north/south cross section along the coast (Figs. 31 and 32) shows a cool dome over the plant area extending from above 500 ft up to the limit of 3000 ft. Two warm tongues appear to extend northward in the direction of wind flow. The moisture picture also shows a moist dome over the plant with a tongue of moisture extending northward. There is a slight relatively dry area from 1100 to 1400 ft, but it is still much more moist than areas 1000 ft above or below.

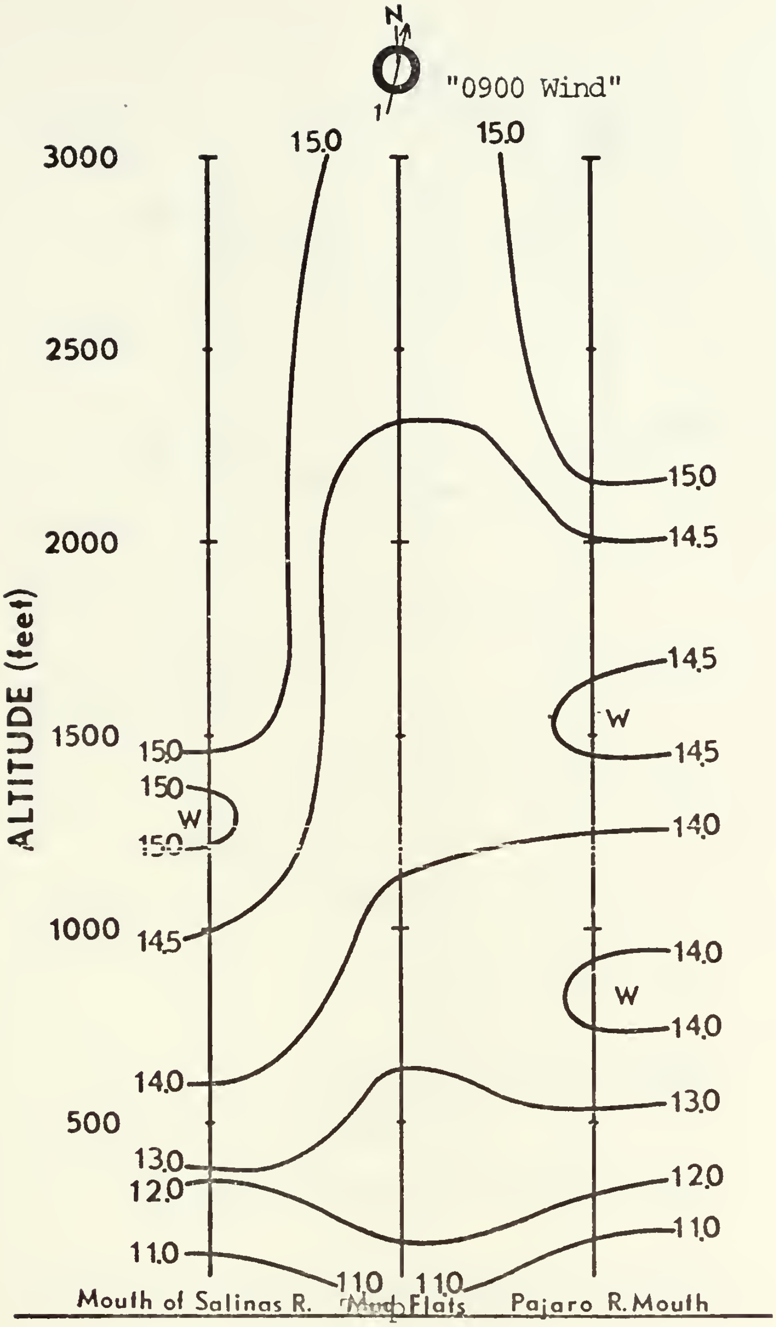
A similar pattern of temperature and moisture appears in the east/west cross sections (Figs. 33 and 34) though the effect of low-level heating inland is readily apparent only three miles inland from the coast.

The cool areas above the plant are probably associated with the local plant-generated updraft carrying cooler low-level air upward. As this dry low level air moves upward it mixes with the stack emitted moisture and its mixing ratio is raised from 7.5 g/kg to 8.8 g/kg.

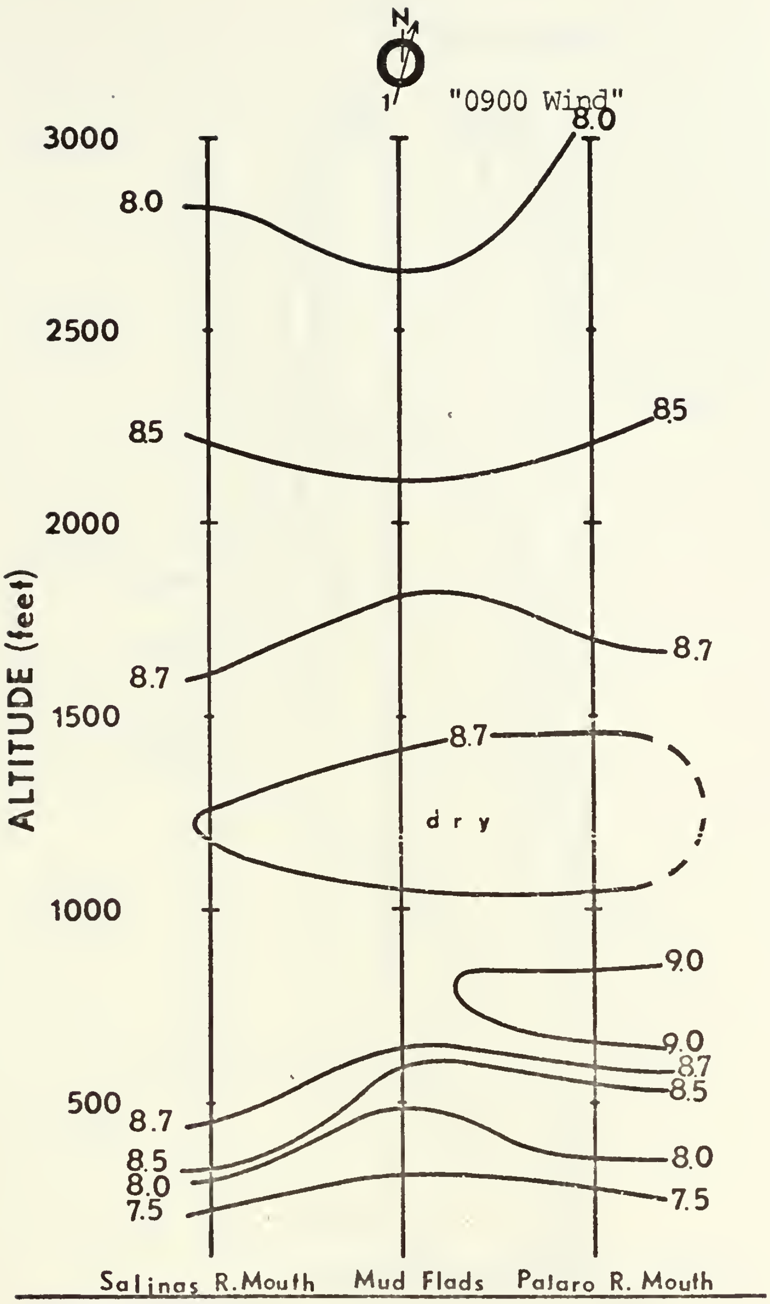
The east/west cross sections (Figs. 35-38) north and south of the plant do not show either of these characteristics. There is, however, again evidence of the transport of properties downstream. As on 11 June the northeastern corner of the sounding pattern (downwind from the plant) shows a temperature and moisture maximum between 1000 ft and 1800 ft. No such strong, well defined pattern exists in the cross section south of the plant (Figs. 35 and 36).

The north/south cross section inland from the plant (Figs. 39 and 40) further reinforces this picture and tends to reflect the diffusion of plant emissions, especially moisture north and west of the plant area.

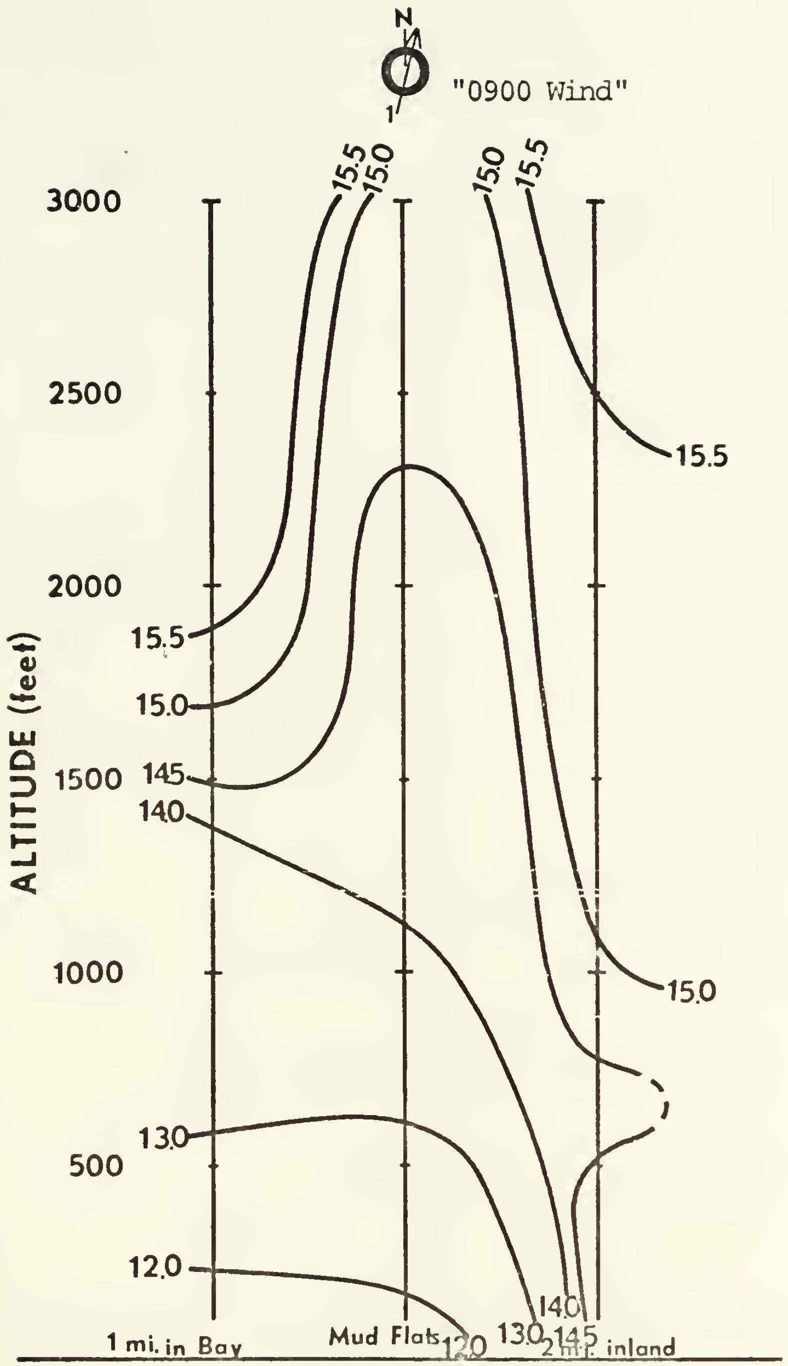
Plant waste heat ranged from 1241 x 10^6 BTU/hr at 0800 to 1305 x 10^6 BTU/hr at 1000 while fuel consumption was approximately 48% during the entire sounding period.



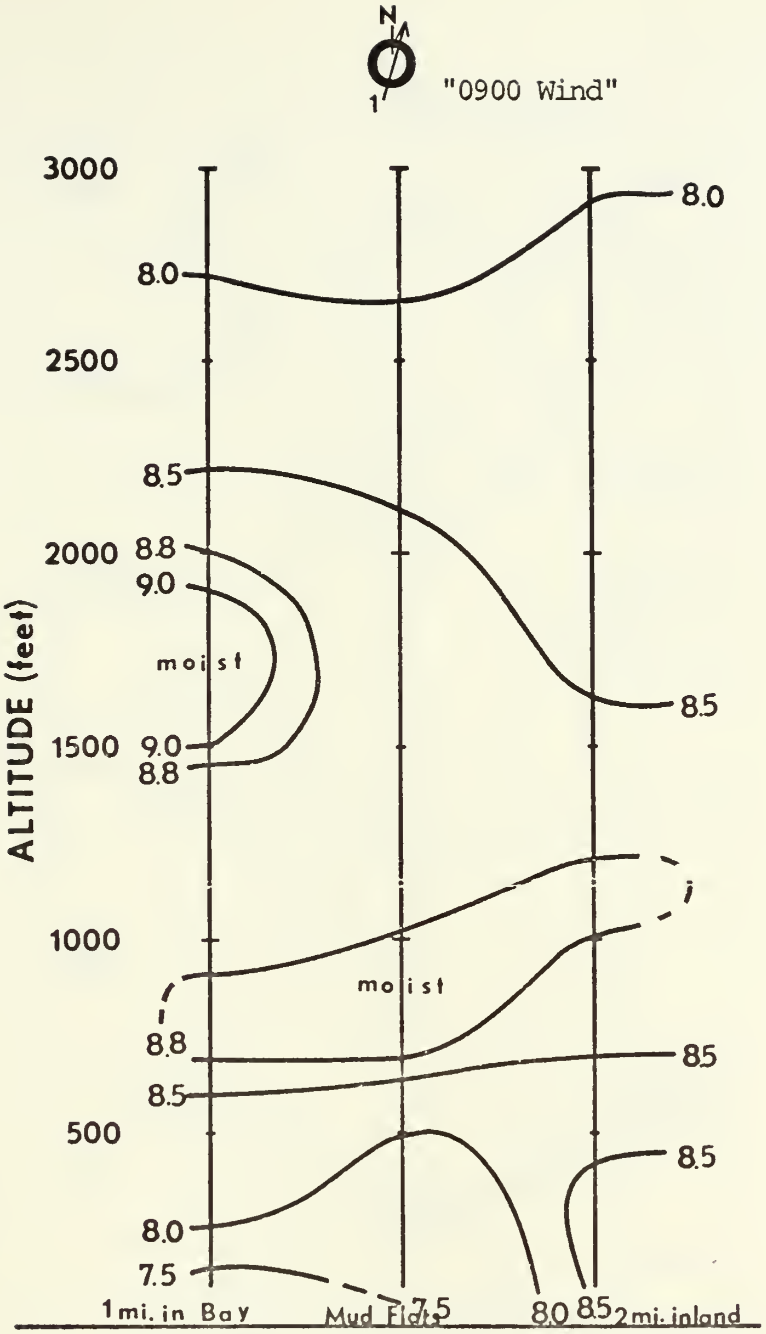
TEMP (°C) 9 JULY 1971
NORTH/SOUTH CROSS SECTION
ALONG COAST
FIGURE 31



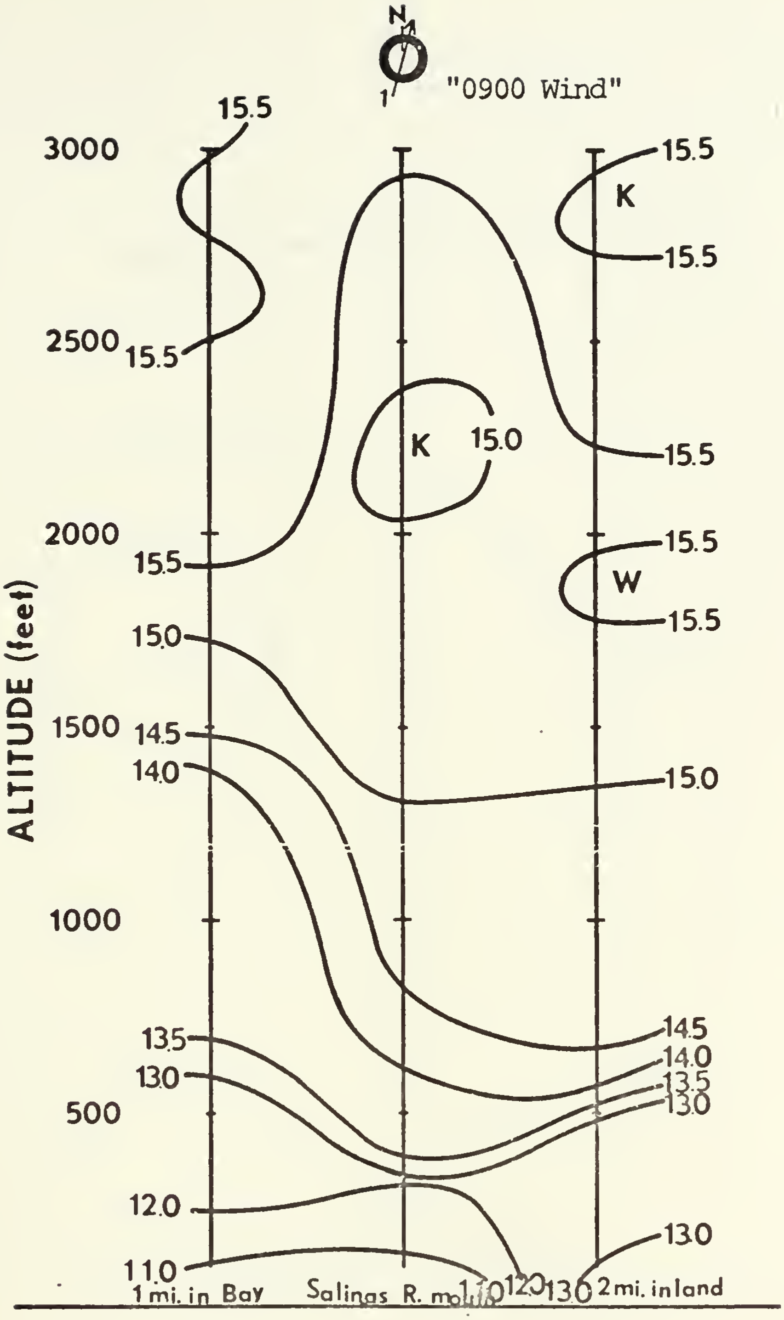
MIXING RATIO (g/kg) 9 JULY 1971
NORTH/SOUTH CROSS SECTION
ALONG COAST
FIGURE 32



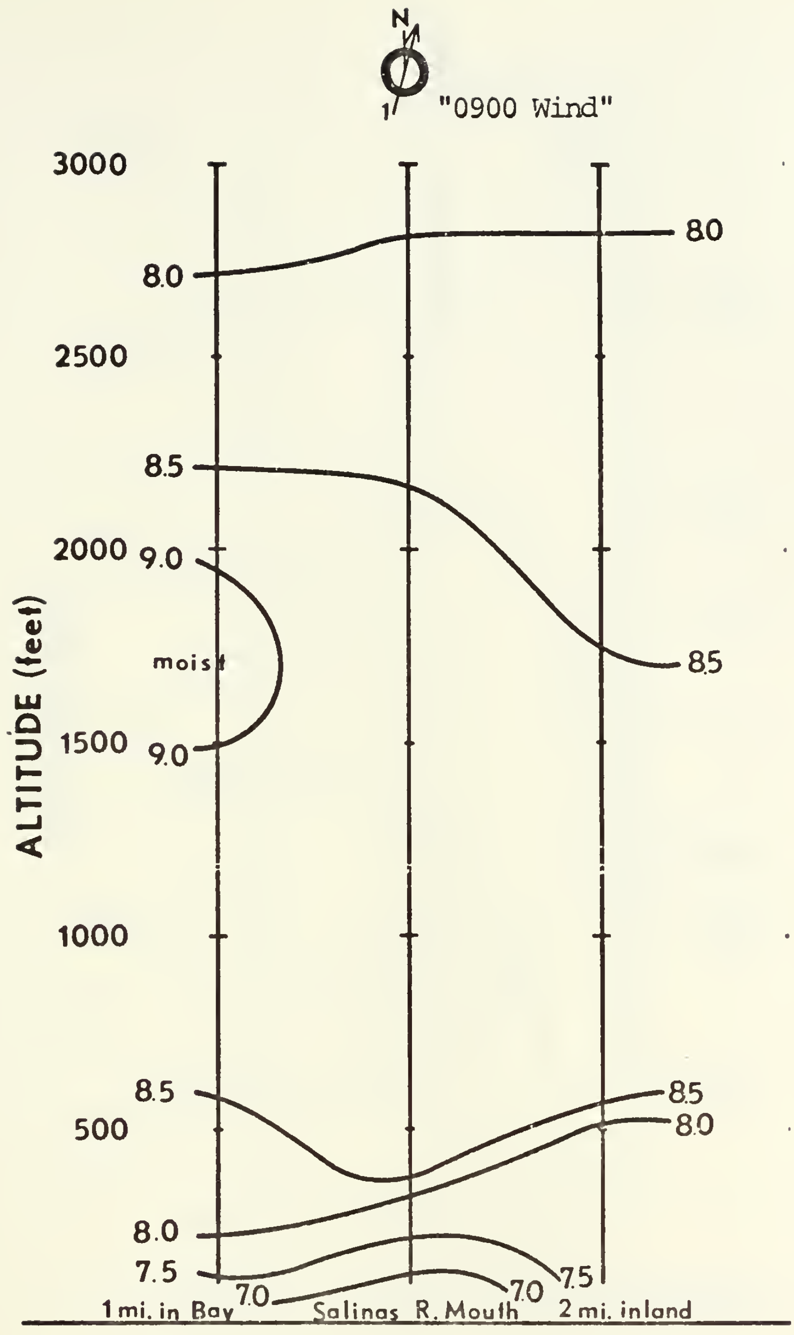
TEMP (°C) 9 JULY 1971
EAST/WEST CROSS SECTION
THROUGH PLANT
FIGURE 33



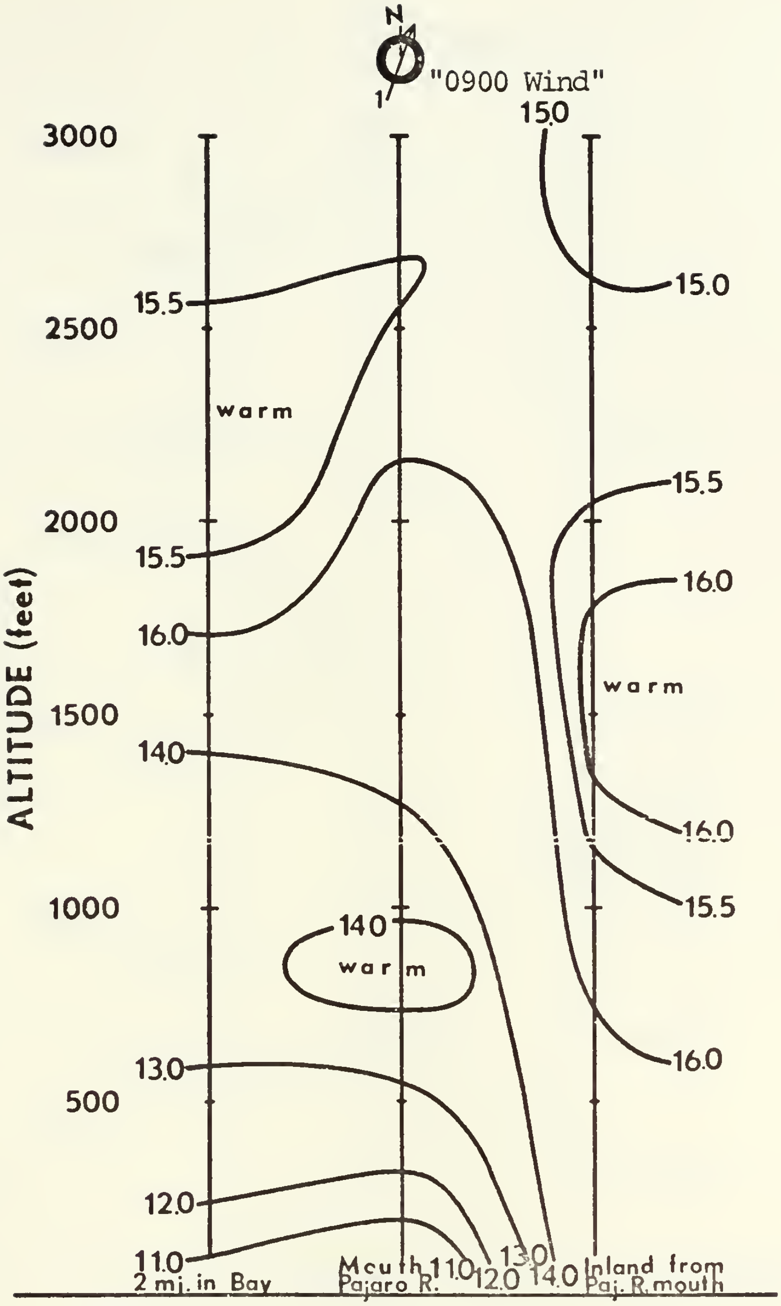
MIXING RATIO (g/kg) 9 JULY 1971
EAST/WEST CROSS SECTION
THROUGH PLANT
FIGURE 34



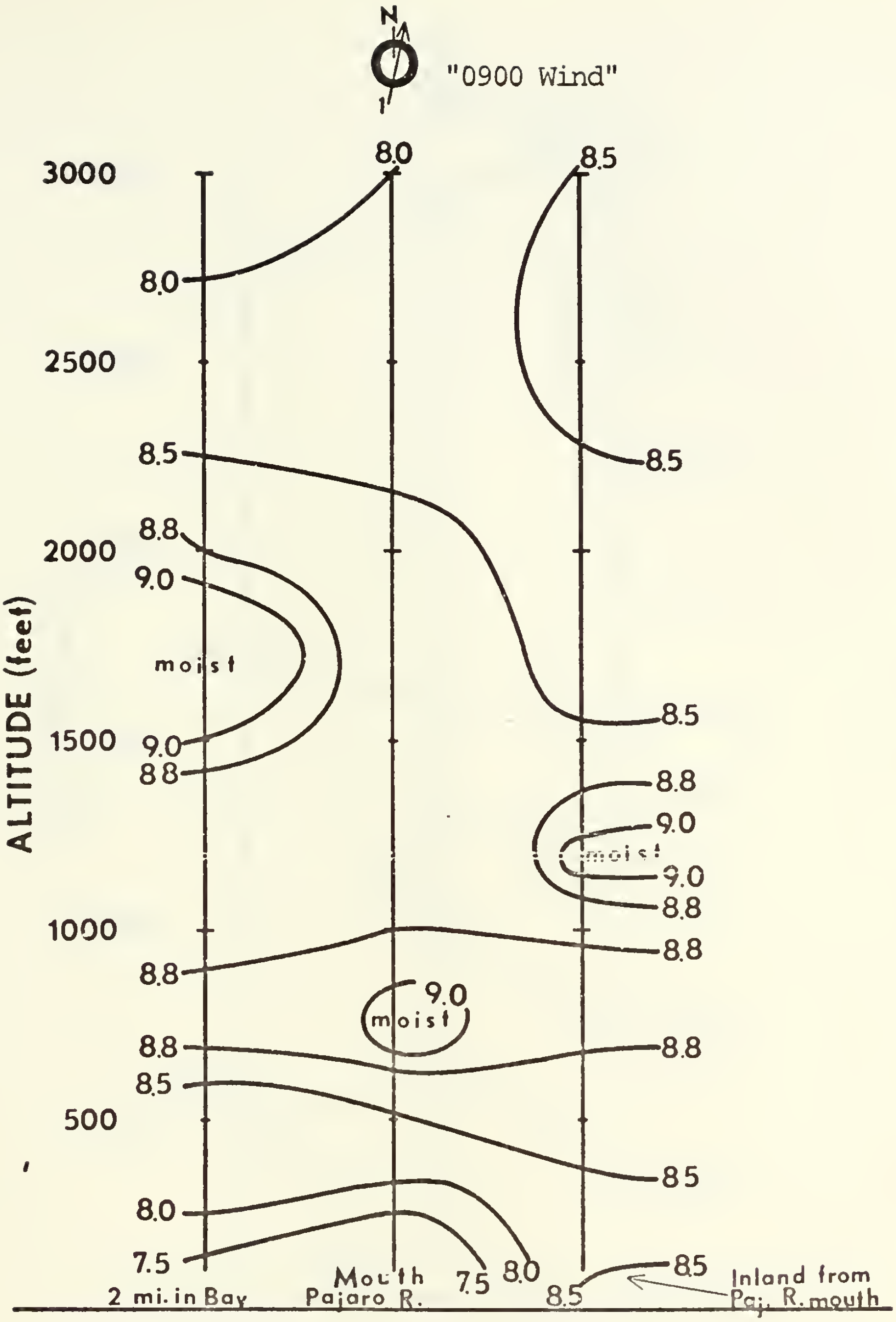
TEMP (°C) 9 JULY 1971
EAST/WEST CROSS SECTION
SOUTH OF PLANT
FIGURE 35



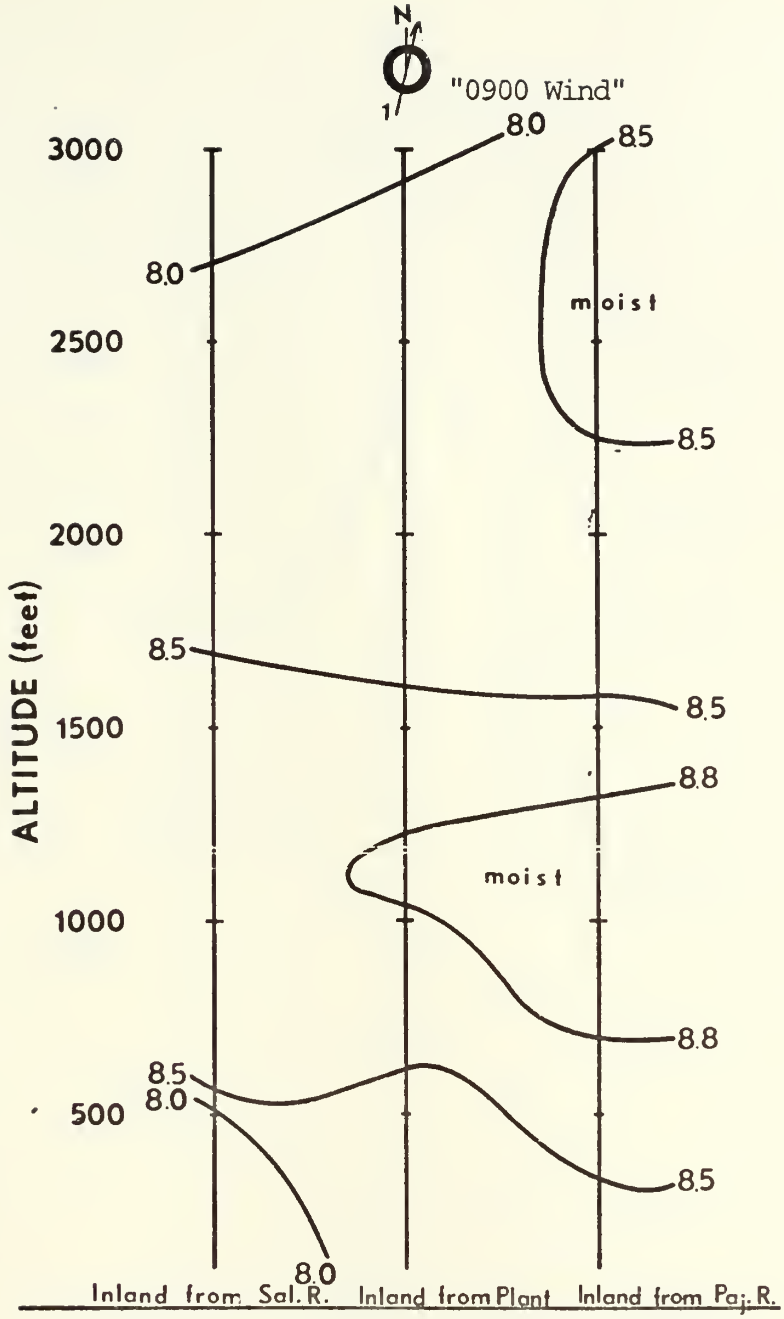
MIXING RATIO (g/kg) 9 JULY 1971
EAST/WEST CROSS SECTION
SOUTH OF PLANT
FIGURE 36



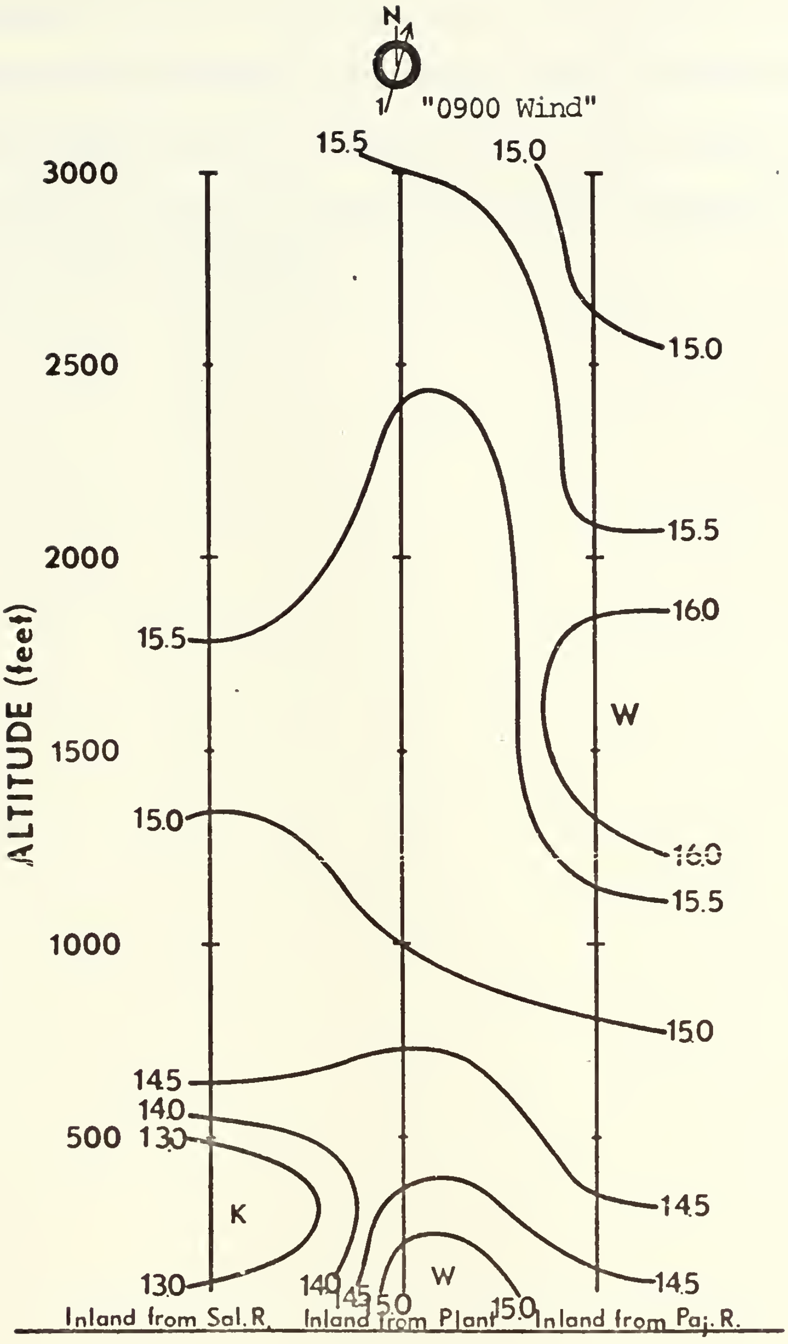
TEMP (°C) 9 JULY 1971
WEST/EAST CROSS SECTION
NORTH OF PLANT
FIGURE 37



MIXING RATIO (g/kg) 9 JULY 1971
WEST/EAST CROSS SECTION
NORTH OF PLANT
FIGURE 38



MIXING RATIO (g/kg) 9 JULY 1971
NORTH/SOUTH CROSS SECTION
INLAND FROM PLANT
FIGURE 39



TEMP (°C) 9 JULY 1971
NORTH/SOUTH CROSS SECTION
INLAND FROM PLANT
FIGURE 40

This completed the data collection phase of the project. Two additional flights were attempted during July, but these were aborted due to hazardous flying conditions brought on by heavy coastal fog. Because all stocks of humidity elements on hand were expended, no further flights could be attempted.

This completed the data collection phase of the project. Two additional flights were attempted during July, but these were aborted due to hazardous flying conditions brought on by heavy coastal fog. Because all stocks of leafleting materials on hand were expended, no further flights could be arranged.

V. RESULTS, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY OF RESULTS

The nine cases presented in this thesis divide themselves naturally into three groups, two classified by the inversion and one classified by clouds. These groups consist of:

1. Inversion base above stack level (7 December 1970 and 6 April 1971).
2. No inversion or inversion below stack level (22 January 1971, 29 January 1971, 1 April 1971, 1 May 1971, and 9 July 1971).
3. Cloud- or fog-restricted operations (1 June 1971 and 11 June 1971).

Several other groupings could be suggested such as synoptic situation (pre-frontal passage, post-frontal passage, etc.) or wind characteristics (onshore or offshore breeze, low or high velocities, etc.). It was decided that since the inversion is the most dominant and persistent weather phenomenon, catagories which were inversion-related should be chosen. In seven of the nine cases an inversion was either directly evident in the readings obtained or was evident in a qualitative sense from the cloud bases observed and temperature profiles extrapolated downward below 100-200 ft. An example of this last case is 9 July 1971 where the temperature ranges from 11C at 100 ft to 15C in the vicinity of 1500 ft and above. This indicated an inversion base below 100 ft with a temperature below 11C.

Taking the three cases separately, one finds that on days when the inversion was above stack levels a lowering of the inversion without apparent intensification occurred in the vicinity of the power plant. In one of the two cases (7 December 1970) an apparent warming also occurred, above 2000 ft. Moisture maxima also occurred above the power plant on the above date and these appeared stratified into two layers.

For the cases where no inversion could be detected or the inversion was below stack level, most temperature profiles were fairly non-descript except for 9 July 1971 where actual cooling is apparent in the column above Moss Landing. All the cases in this category tend to show clearly the effects of moisture, having well defined moisture maxima located above or downwind from the power plant area. This category also accounted for all the days when the wind regime had a recognizable effect on the stack emissions.

The third case, cloud- or fog-restricted operations, reflected both temperature and moisture maxima over the power plant area but with no noticeable effect on the inversion except for the unique and dramatic visual observation of 9 June 1971.

It is apparent that the atmospheric moisture content is much more sensitive to the discharges of the stacks than is the temperature structure. Moisture maxima are often present where there is no temperature maximum, but the reverse was almost never observed.

A tabular representation of the three general cases is contained in Appendix C.

Finally, one might conjecture that the large amount of water vapor released into the air from the stacks would quickly diffuse and the effects would not be felt over any great distance.

To answer this conjecture, assume that the power plant is operating at 50% of capacity and therefore is exhausting 500,000 gal of water per hour. Assume that a wind is blowing with sufficient velocity to carry the moisture away and thoroughly mix it. Also assume an inversion at 3000 ft which traps

all of the emitted water vapor below it. For simplicity, assume constant density (standard atmospheric density of 1.225×10^{-3}g/cm^3) up to 3000 ft. Given this situation the following parameters can be set forth:

a. 1.89×10^9g/hr of water vapor release.

b. 349ft^3 of air per kg of air throughout.

c. 659.6×10^9ft^3 of air whose mixing ratio is raised one g/kg.

This volume of air corresponds to a volume 3000 ft high (to the base of the inversion), one mile wide and eight miles long in which the moisture content is raised by one g/kg. This is quite realistic when compared to the data where increases in mixing ratio ranged from one-half to one gram per kilogram in bands much thinner than 3000 ft and to distances of up to five miles.

Further, at 50% capacity stack emitted heat amounts to 39×10^{10}cal/hr. Using the above assumptions and a specific heat at constant volume of 0.171 cal/g deg one finds that about 3.9×10^{12} calories would be required to raise this volume of air one degree. The heat available is only enough to raise this volume by 10^{-2} degrees certainly well below the sensitivity of the instrument. This also supports the data where moisture effects were often detectable but not those from emitted heat.

B. CONCLUSIONS

From the nine data sets obtained it is clear that there is a definite effect on the surrounding atmosphere and that these effects may extend for an appreciable distance downstream from the point of entry. The nature of the effect on the atmosphere appears to be very strongly tied to the position of the inversion with respect to stack height and also to cloud structure, if clouds are present.

If the inversion is above stack level, the base appears to be lowered in the vicinity of the source. If clouds are present, the emitted moisture tends to thicken the clouds or at least lower the cloud bases and probably the associated inversion. If the inversion base is below the stack level or there is no inversion, then it appears that the wind regime becomes important. A rapid dispersal of plant emissions occurs, but these properties, especially moisture, were in evidence at a considerable distance downwind from the plant.

Radiated heat from plant equipment at low levels, which is very nearly a constant, also seems to play an important role especially when weather conditions are in transition such as in the 9 June 1971 case and also evident in the 9 July 1971.

Though not directly addressed to the question of pollution, at least one conclusion can be drawn drom the study. If one assumes that pollutants remain entrained in the major stack emissions, i.e., water vapor and heat, then the fate of these emissions is also the fate of the pollutants. This has negative as well as positive consequences. Negatively, the trapping of pollutants in a cloud layer or below an inversion allows for their concentration in the very lowest layers of the atmosphere. Positively, any predictability or forcast expertise gained in relation to changes in the inversion will allow for a similar scheme in predicting pollutant dispersal.

C. RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

Four recommendations are made herewith. First, that the concept of this study be continued not only in this geographic locale, but in others as well. More supporting data, a greater density of data points, and varying locations

are needed to further confirm or perhaps deny the picture as presented here. This continuation should also include other industrial sights such as steelmills, refineries, and other power plants.

Second, that careful consideration be given to this study and others like it in the future when a large industrial complex location is being considered.

Third, that equipment manufacturers investigate the possibility of the development of equipment which is easily portable and which can be set up, used, dismantled, and moved in a minimum amount of time. Fifteen minutes start to finish is considered ideal. The equipment should also be able to penetrate fog and low clouds and still relay all measured parameters including altitude back to the observer. Neither the wiresonde set nor the helicopter aerograph set possessed this all important capability. It should also have a low cost per data point sampled so that economics would not tend to limit data point density.

Finally, as an adjunct to this study, a precipitation study should be initiated. An array of rain gauges positioned downwind from the plant would hopefully yield ample substantiating data to the effect of moisture. It is felt that this would be an especially worthy project during the summer when any measurable moisture is in the form of dew, mist, or drizzle from the coastal fog and low stratus clouds. At this time plant-emitted moisture could make up a good percentage of the downwind moisture and quite possibly increase the precipitation.

APPENDIX A

Date:____________________ Run #__________

Start Time:________________

Run Description

	Start	Stop
Wet Bulb		
Dry Bulb		
RH		
Recorder RH		

Ht (ft)	Press. (mb)	Time		Temp (°C)	Humidity		Mag Bearing	Range
		Clock	Rcdr.		RH	Specific		

APPENDIX B

```
C      A PROGRAM TO COMPUTE MIXING RATIO,M(I) FROM RELATIVE
C      HUMIDITY,RH(I).ADDITIONAL INFORMATION NOT USED IN
C      THE COMPUTATIONS ARE DATE (IDATE),RUN NUMBER (IRUN)
       IMPLICIT REAL*4(M)
       DIMENSION TEMP(100),RH(100),ES(100),M(100),P(100),
      1MS(100)
     1 READ (5,100) IDATE
     2 READ (5,100) IRUN
       IF(IRUN .EQ.99)GO TO 99
     4 READ (5,100) N
     6 READ (5,101) (TEMP(I),I=1,N)
       READ(5,102)(P(I),I=1,N)
       DO 9 I=1,N
       TEMP(I)=TEMP(I)+273.1
     9 CONTINUE
     7 READ (5,101) (RH(I),I=1,N)
   100 FORMAT(I6)
   101 FORMAT(8F5.1)
   102 FORMAT(8F6.1)
C      COMPUTE SATURATED VAPOR PRESSURE ES(I) AND MIXING
C      RATIO M(I)
       A=597.3/.1102
       DO 10 I=1,N
       ES(I)=6.11*EXP(A*((1./273.1)-(1./TEMP(I))))
       WRITE(6,101)ES(I)
       MS(I)=(.622*ES(I))/(P(I)-ES(I))
       M(I)=(MS(I)*RH(I))*10.
    10 CONTINUE
       WRITE (6,200)
   200 FORMAT(2X,'DATE',8X,'RUN',/)
       WRITE (6,201) IDATE,IRUN
   201 FORMAT (1X,I6,3X,I6,//)
       WRITE(6,300)
   300 FORMAT(1X,'MIXING RATIO',//)
       WRITE(6,301)(M(I),I=1,N)
   301 FORMAT(8F12.6)
       GO TO 2
    99 STOP
       END
$GO
```

DATA DECK

APPENDIX C

TABLE OF RESULTS

Position of Inversion	Results of Stack Emissions
Inversion base above stack level	Inversion lowered in plant area without apparent intensification
No inversion or inversion below stack level	Little effect on temperature, moisture tends to be conserved, moisture maxima transported downward
Cloud base or fog at low levels, inversion assumed at cloud base	Temperature and moisture conserved, possible lowering of cloud bases, effects generally unpredictable.

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13. ABSTRACT

Using a steam electric generating plant as the source, an investigation was made into the local atmospheric effect of a large industrial heat and moisture source. Data collection was attempted with ground- and helicopter-borne equipment with a final resort to the helicopter when the ground equipment collection techniques proved unsatisfactory. Cross sections of temperature and moisture were drawn from this data and yielded some very interesting profiles.

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14 KEY WORDS	LINK A		LINK B		LINK C	
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Wiresonde						
Inversion						
Power Plant						

Thesis
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An investigation into the effect of an industrial heat and moisture source on local atmospheric conditions.